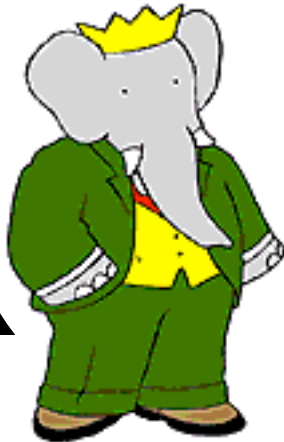# Baryonic
B Decays at BABAR

Stephanie Majewski
Stanford University

Brookhaven National Laboratory Seminar
June 1, 2007

Baryonic *B* Decays: Motivation

Baryon Production in B decays

Compare 2:3:4-body

B decay rates

Baryon-antibaryon

"threshold enhancement"

Baryonic *B* Decays: Motivation

Baryon Production in B decays
Compare 2:3:4-body *B* decay rates
Baryon-antibaryon "threshold enhancement"

Search for exotic baryon states

Angular analysis to determine baryon spin

Baryonic *B* Decays: Motivation

Baryon Production in B decays
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Baryon-antibaryon "threshold enhancement"

Search for exotic baryon states

Angular analysis to determine baryon spin

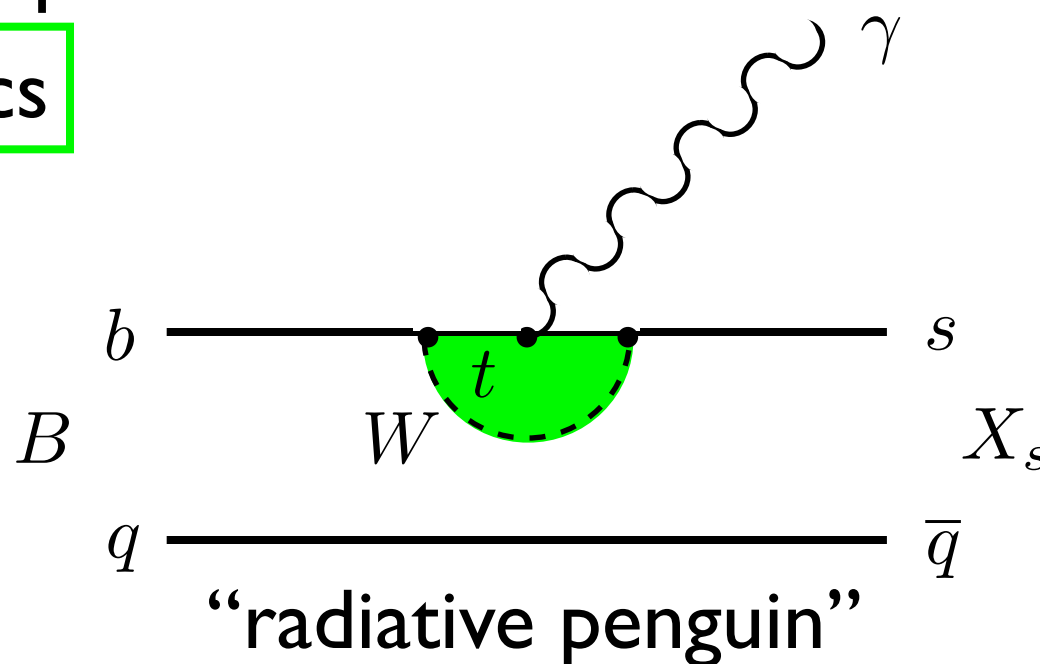Radiative baryonic *B* decays could probe new physics
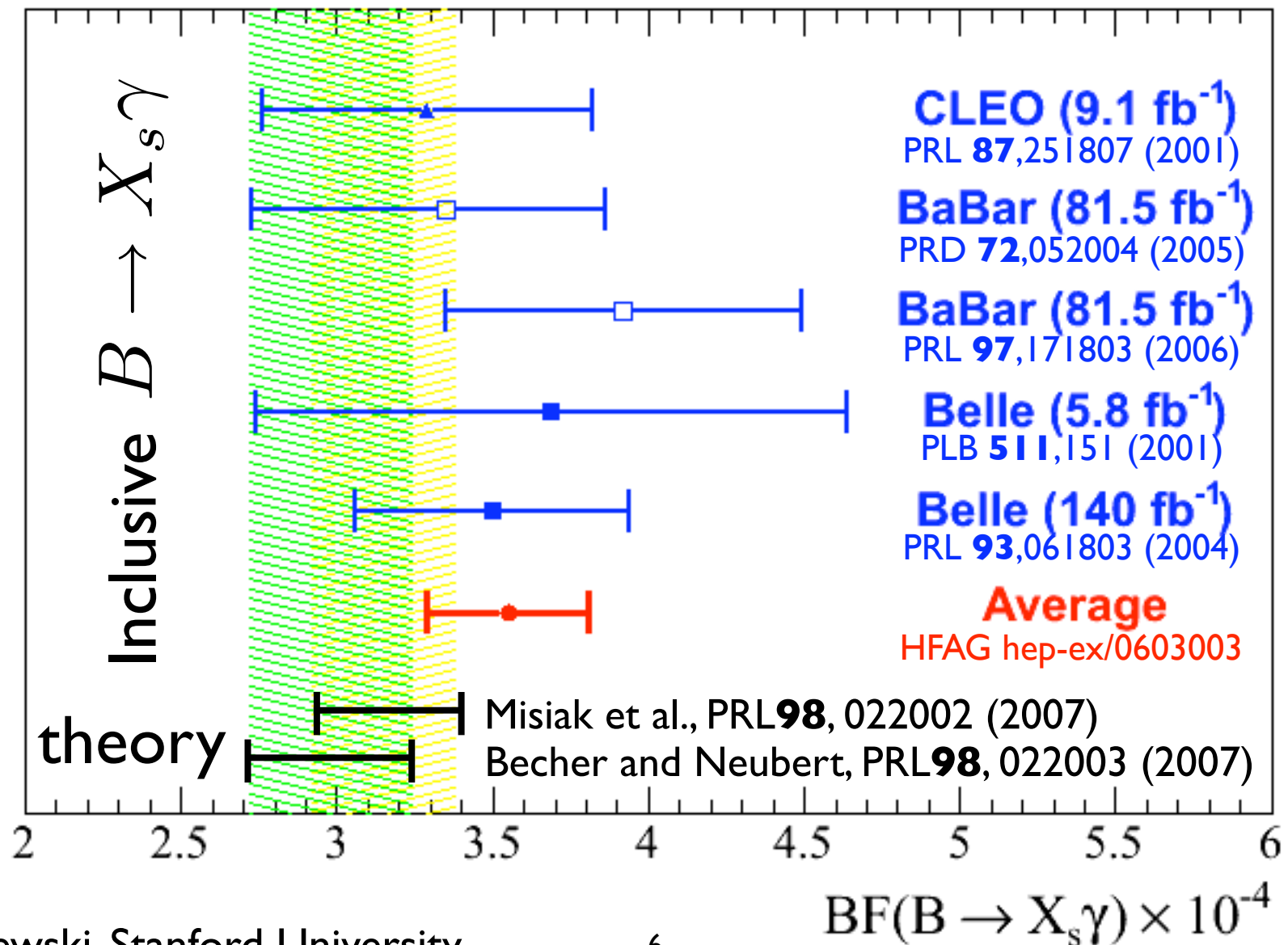$b \longrightarrow s\gamma$

Radiative *B* Decays

Flavor-Changing Neutral Current
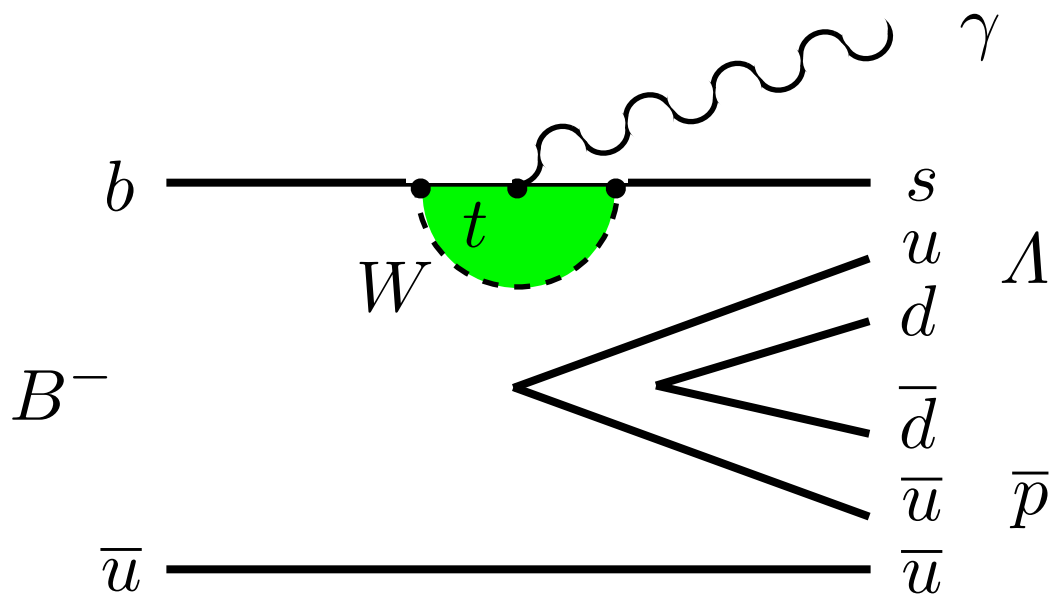- Absent at tree-level in SM
- Dominated by *W-t* loop

Sensitive to new physics

"radiative penguin"

Radiative *B* Decays

CLEO (9.1 fb⁻¹)
PRL **87**,251807 (2001)

BaBar (81.5 fb⁻¹)
PRD **72**,052004 (2005)

BaBar (81.5 fb⁻¹)
PRL **97**,171803 (2006)

Belle (5.8 fb⁻¹)
PLB **511**,151 (2001)

Belle (140 fb⁻¹)
PRL **93**,061803 (2004)

Average
HFAG hep-ex/0603003

theory

Misiak et al., PRL**98**, 022002 (2007)
Becher and Neubert, PRL**98**, 022003 (2007)

Inclusive $B \to X_s \gamma$

$$BF(B \to X_s \gamma) \times 10^{-4}$$

Radiative Baryonic *B* Decays

Measured by Belle:
arXiv:0704.2672
with 410 fb⁻¹

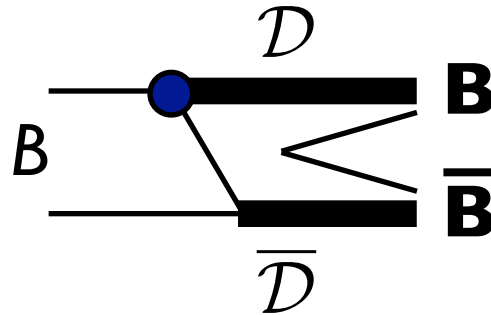$$\mathcal{B}\left(B^{-} \rightarrow \Lambda\overline{p}\gamma\right) = (2.5 \pm 0.4 \pm 0.2) \times 10^{-6}$$

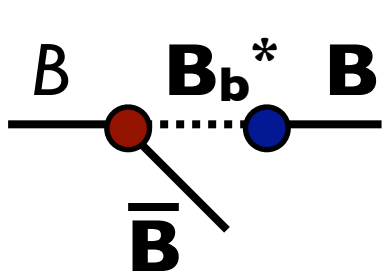**theory**

Cheng and Yang, Phys. Lett. **B533**, 271 (2002): ~ 1.2 × 10^{-6}
Geng and Hsiao, Phys. Lett. **B610**, 67 (2005): ~ 1.0 × 10^{-6}

Theoretical Predictions

- Predict baryonic *B*-meson branching fractions from various models:

  - Pole model, diquark model, QCD sum rules, etc. ...

- Early 90s predictions were much too large
  [e.g., B → Λ_c p theory: $O(10^{-3})$, meas: 2×10^{-5}]

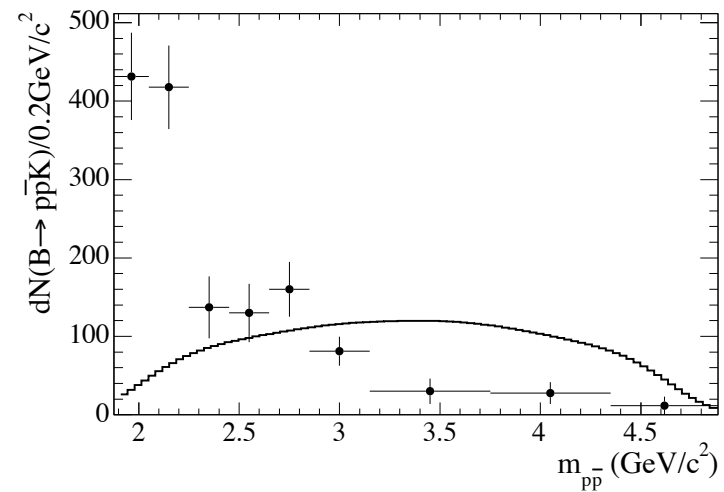- Need experiments to help distinguish models

Features of Baryonic *B* Decays

- **Decay Rates:**
lower Q-value ➡ higher BF

e.g., Charmed baryonic B decays:
BF(2-body):(3-body):(4-body) ~ 1:10:100

$$\frac{\mathcal{B}\left(B^- \to \Lambda_c^+ \overline{p}\pi^-\right)}{\mathcal{B}\left(\overline{B}^0 \to \Lambda_c^+ \overline{p}\right)} = 16.4 \pm 2.9 \pm 1.4$$

- **Threshold enhancement:**
peak near threshold in baryon-antibaryon system

Qualitative Explanation

Baryon (**B**) production is favored when there is "reduced energy release" from the baryon-antibaryon system

W.-S. Hou and A. Soni, PRL **86**, 4247 (2001).

$B \rightarrow \mathbf{B} \bar{\mathbf{B}}$

$m_{\mathbf{B}\bar{\mathbf{B}}} = m_B$

suppressed

$B \rightarrow \mathbf{B} \bar{\mathbf{B}} \, M$

$m_{\mathbf{B}\bar{\mathbf{B}}} < m_B$
recoil meson M
carries away energy

favored

Outline

Results from BABAR....

- $B \to p\overline{p}K$

- $B \to D^{(*)}p\overline{p}(\pi)$

- $B \to \Lambda\overline{p}\pi$

- $B \to \Lambda_c\overline{p}(\pi)$

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BABAR

1.5 T Solenoid
(superconducting)

Cherenkov
Detector
144 quartz bars,
11,000 PMTs

Instrumented
Flux Return
(18−19 layers)

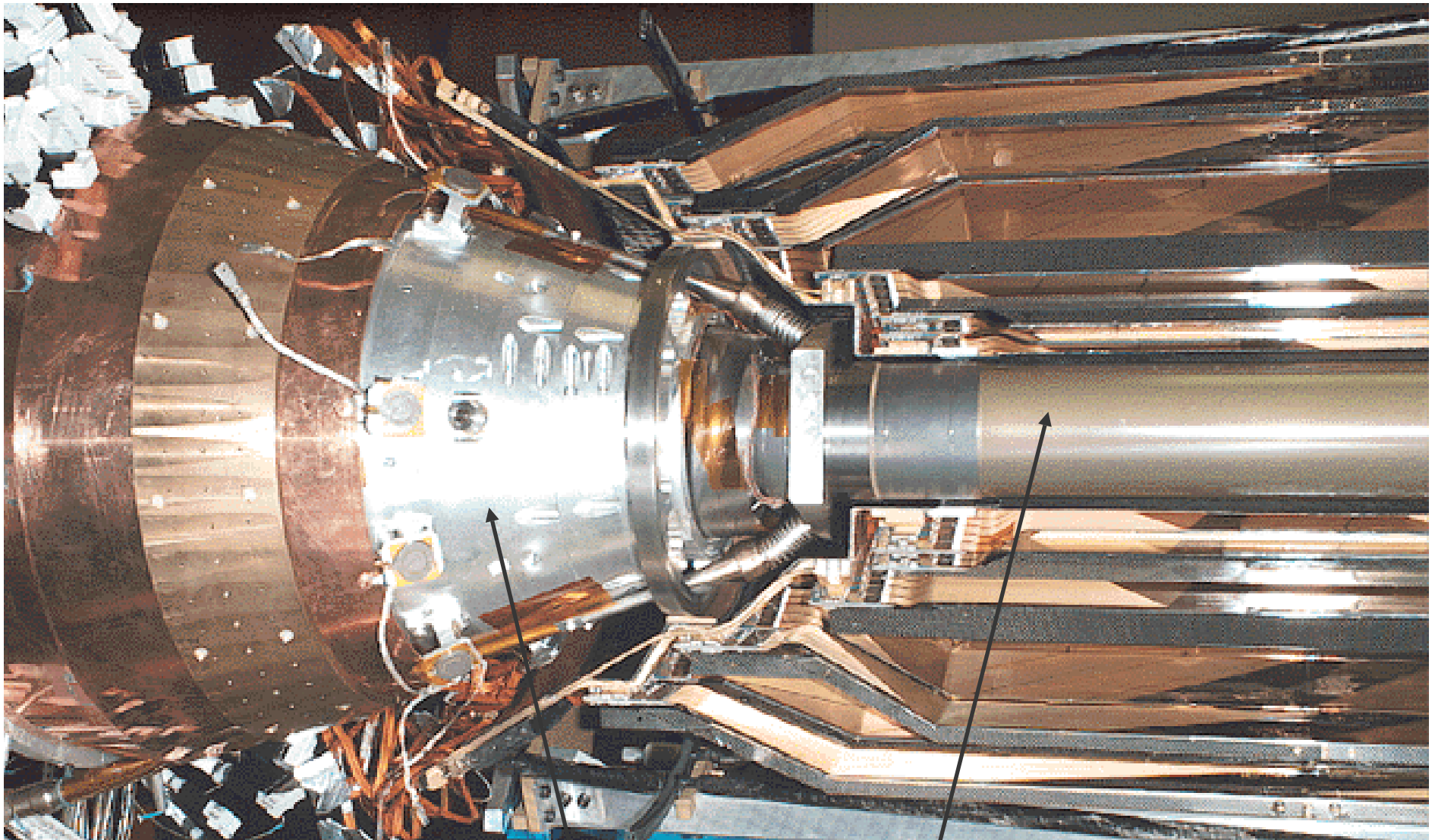Calorimeter
(6580 CsI(Tl) crystals)

e^+ (3.1 GeV)

e^- (9 GeV)

Silicon Vertex
Tracker
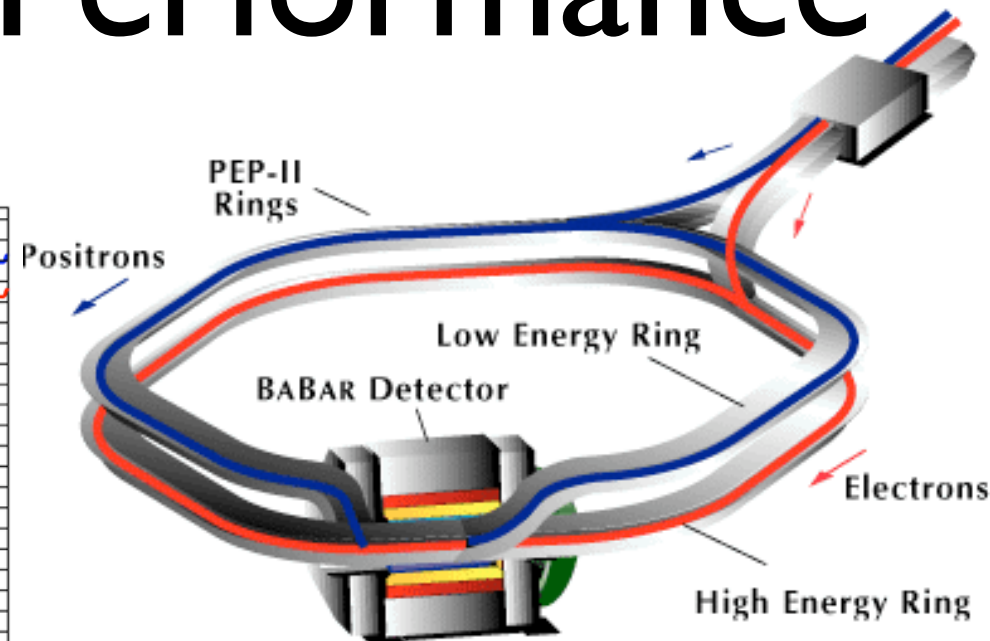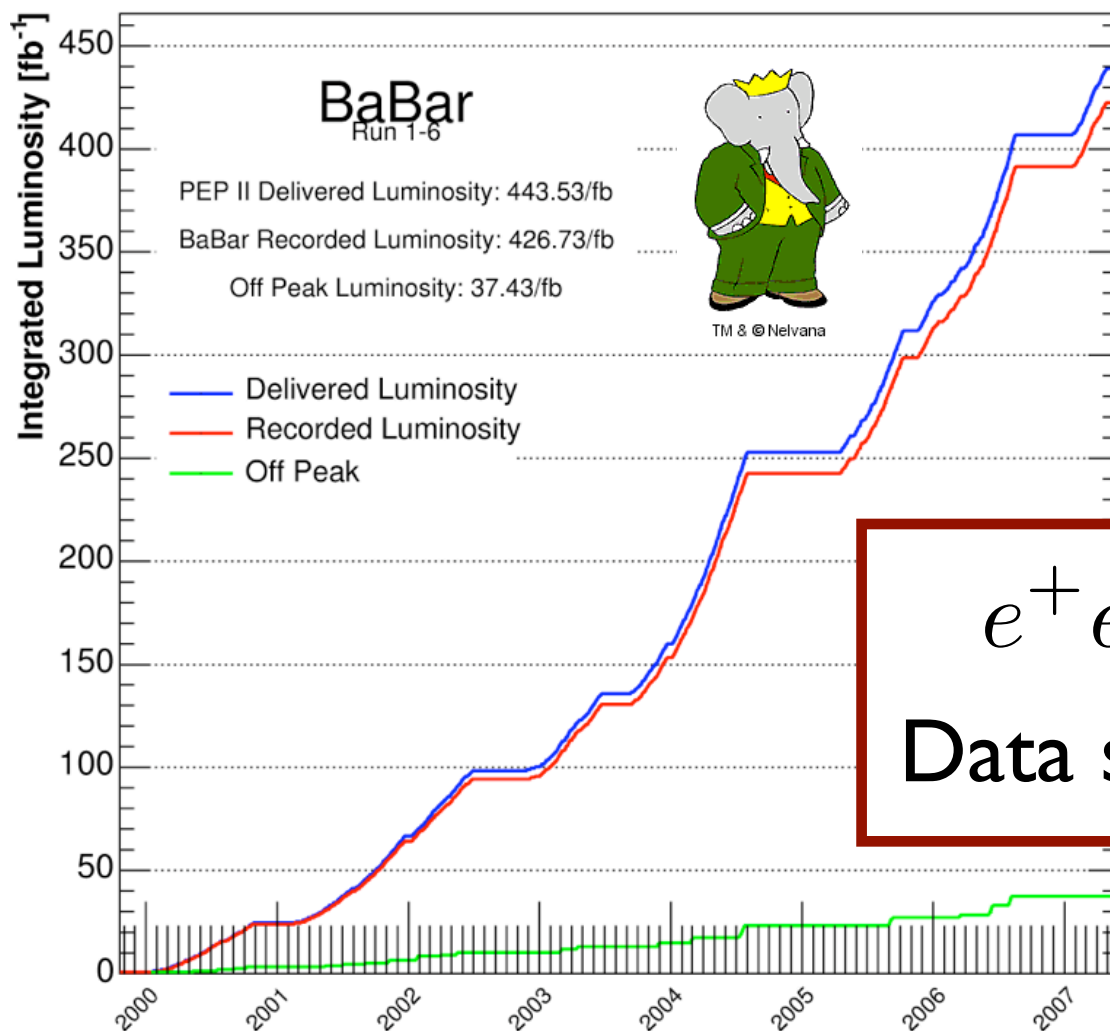5 double-sided
layers

Drift Chamber
40 layers

Silicon Vertex Tracker
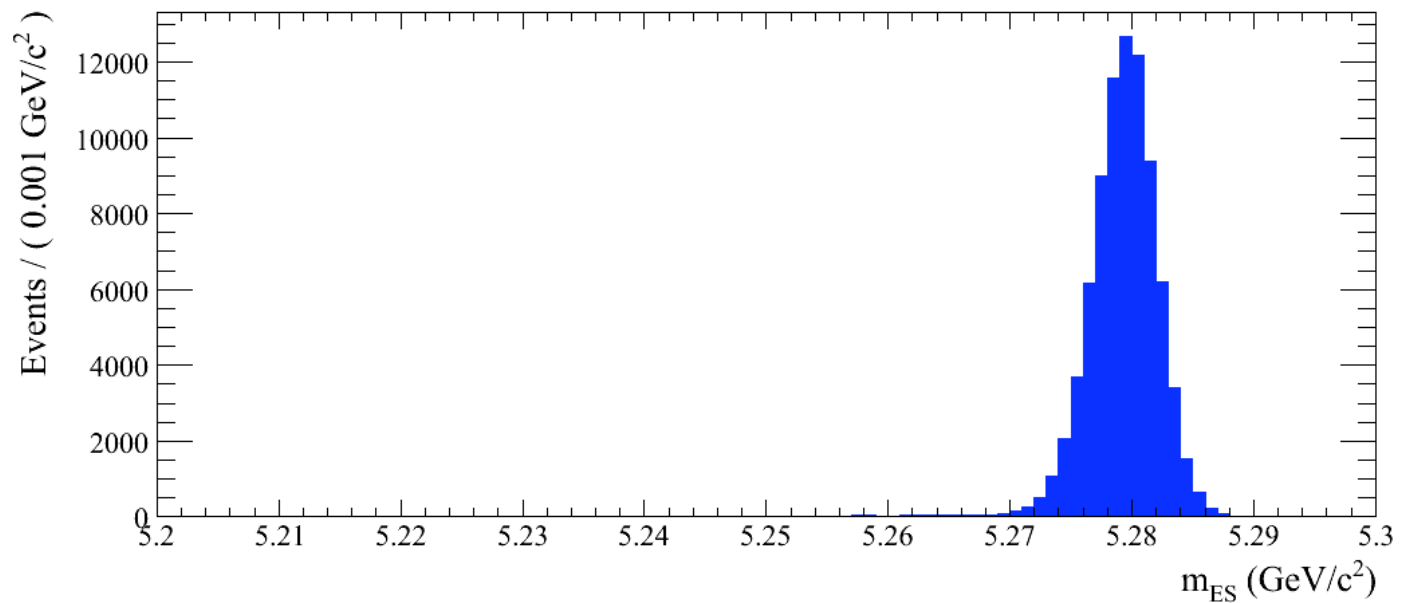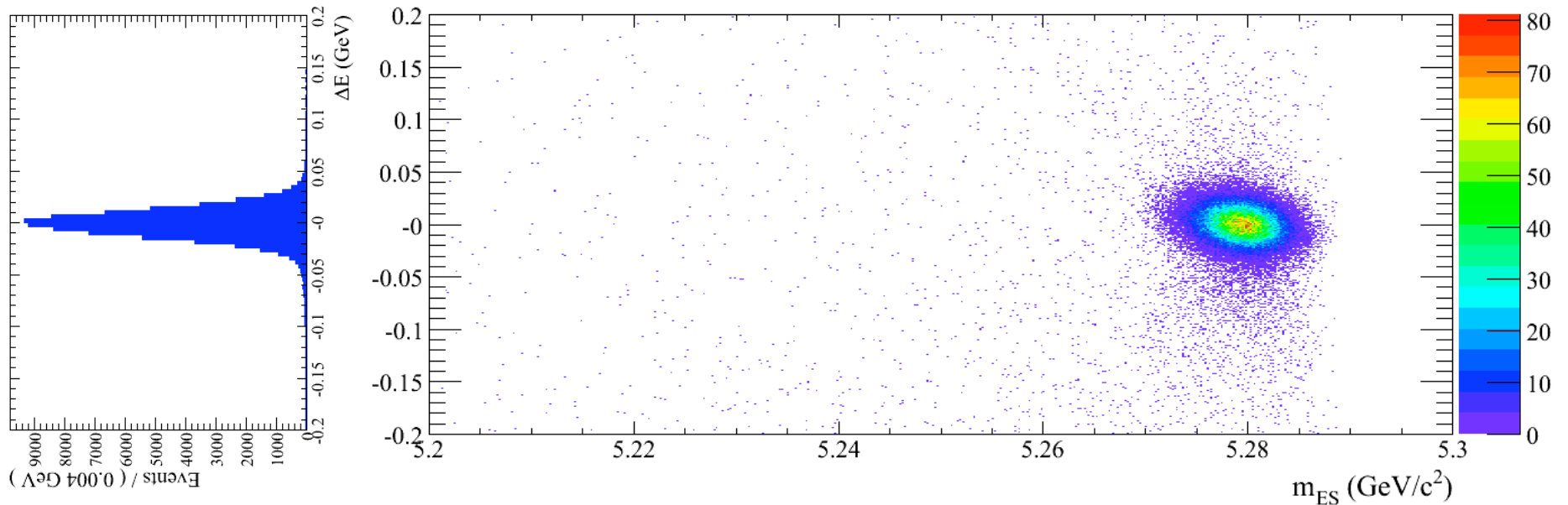

Magnet 13 **Be Beam Pipe**

PEP-II/BABAR Performance

$$e^+ e^- \to \Upsilon(4S) \to B\bar{B}$$

Data set: $383 \times 10^6 \, B\bar{B}$ pairs

Kinematics

$$\Delta E = E_B^* - \sqrt{s}/2$$

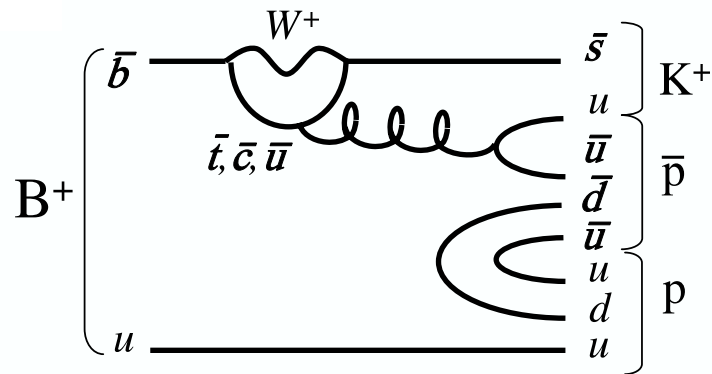$$m_{\text{ES}} = \sqrt{((s/2 + \mathbf{p}_i \cdot \mathbf{p}_B)^2/E_i^2 - \mathbf{p}_B^2)}$$

- $B \to p\overline{p}K$

- $B \to D^{(*)}p\overline{p}(\pi)$

- $B \to \Lambda\overline{p}\pi$
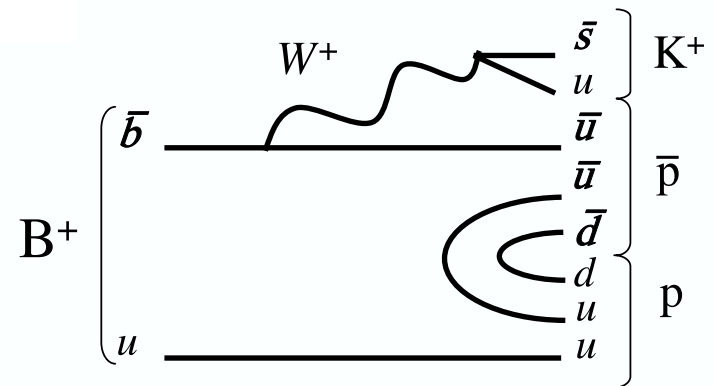
- $B \to \Lambda_c\overline{p}(\pi)$

TM & © Nelvana
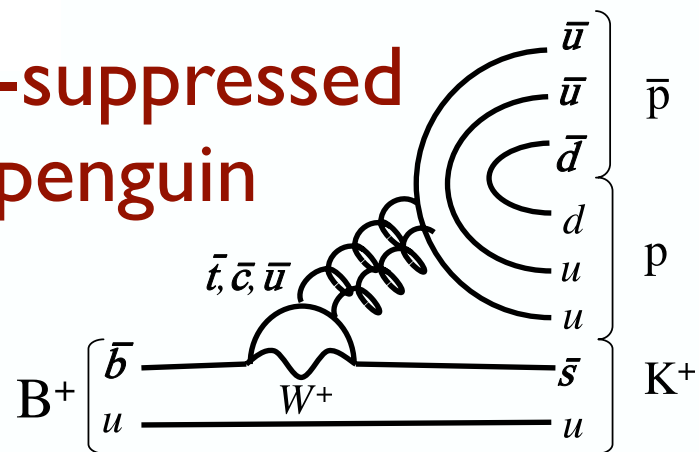
$B^+ \rightarrow p\bar{p}K^+$ Diagrams

penguin

tree

OZI-suppressed penguin

$B^+ \rightarrow p\bar{p}K^+$ Results
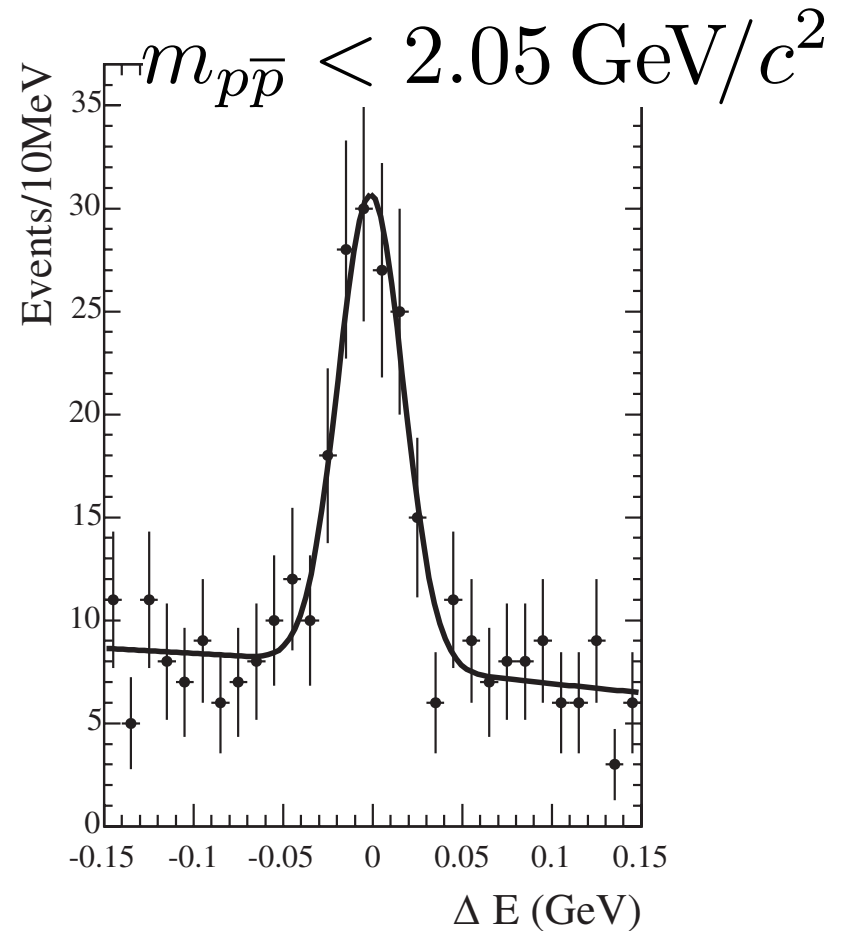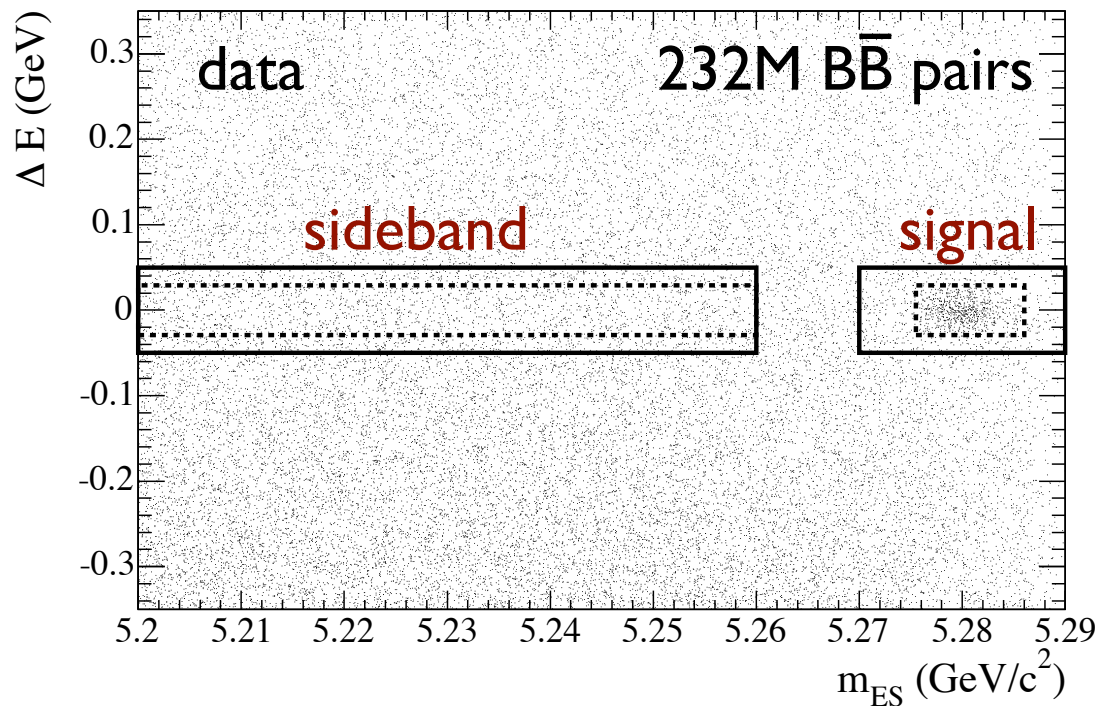
$$\mathcal{B}\left(B^+ \longrightarrow p\overline{p}K^+\right)$$

$$\mathcal{B}\left(B^+ \to p\overline{p}K^+\right)_{\text{tot}} = (6.7 \pm 0.5 \pm 0.4) \times 10^{-6}$$

non-charmonium
signal yield:
433 ± 35

J/ψ

η_c

χ_{c0} χ_{c1} ψ'

χ_{c2}

sideband

Events/10 MeV/c^2

$m_{p\overline{p}}$(GeV/c^2)

S. Majewski, Stanford University

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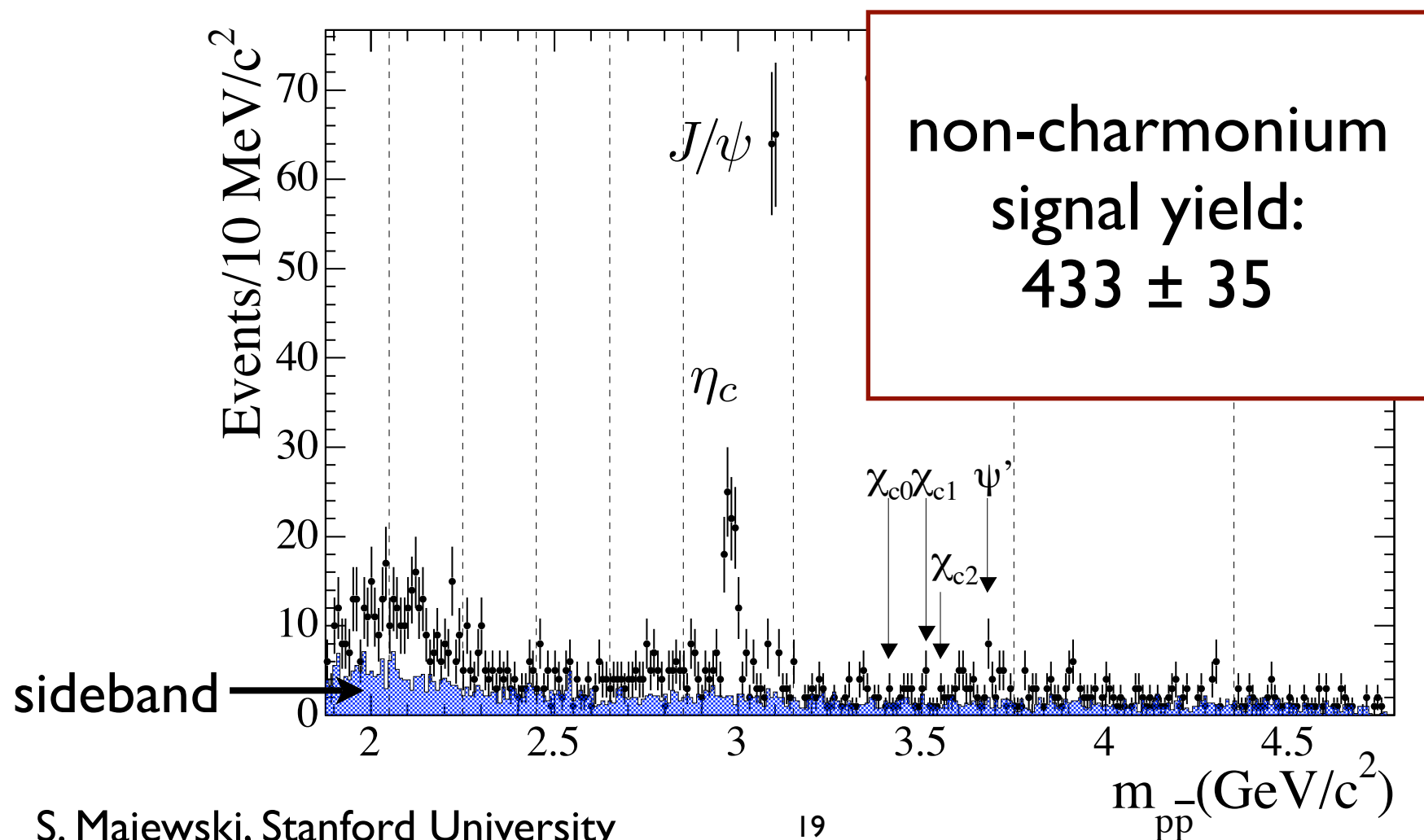
pp̄ Threshold Enhancement
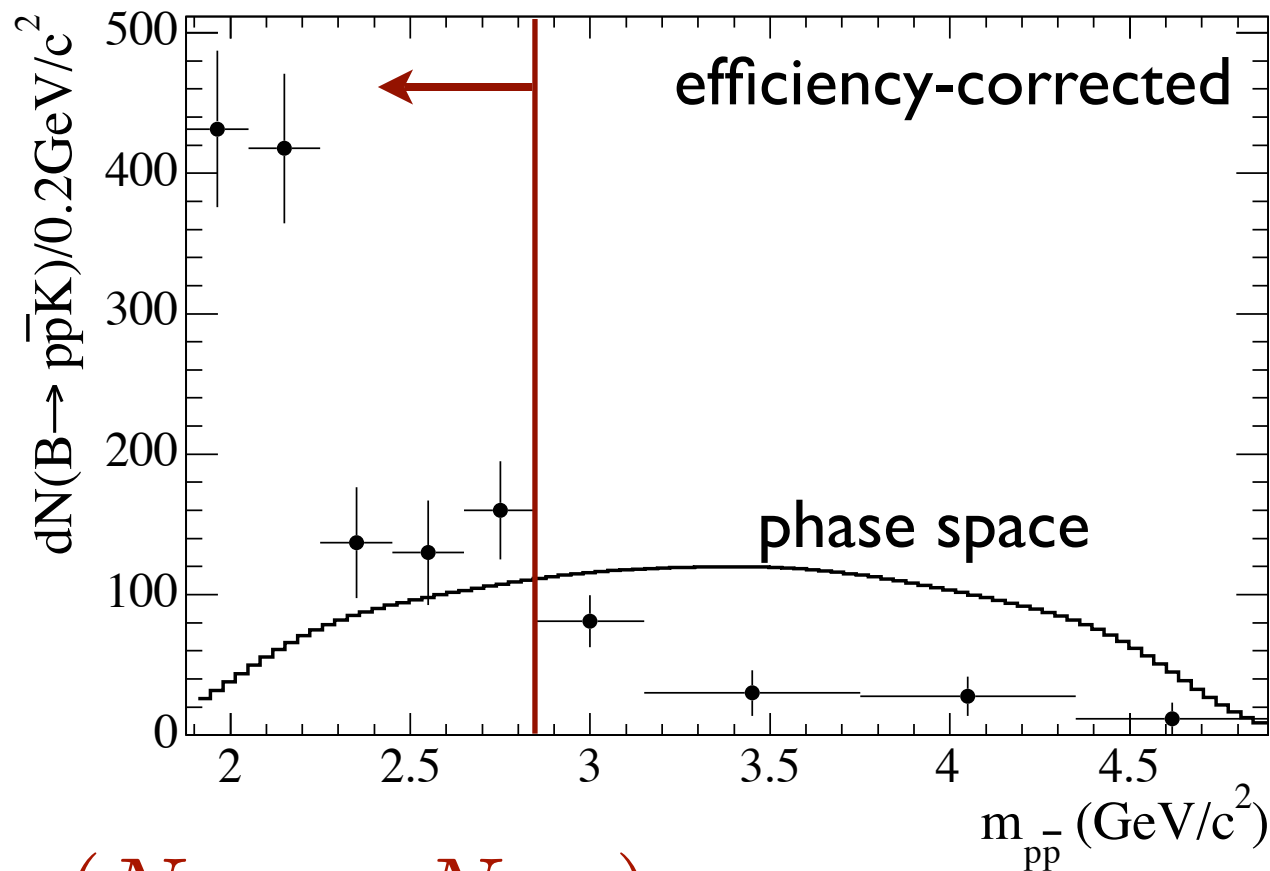
$$A_{ch} = \frac{(N_{B^-} - N_{B^+})}{(N_{B^-} + N_{B^+})} = -0.16^{+0.07}_{-0.08} \pm 0.04$$

p̄pK Dalitz Plot
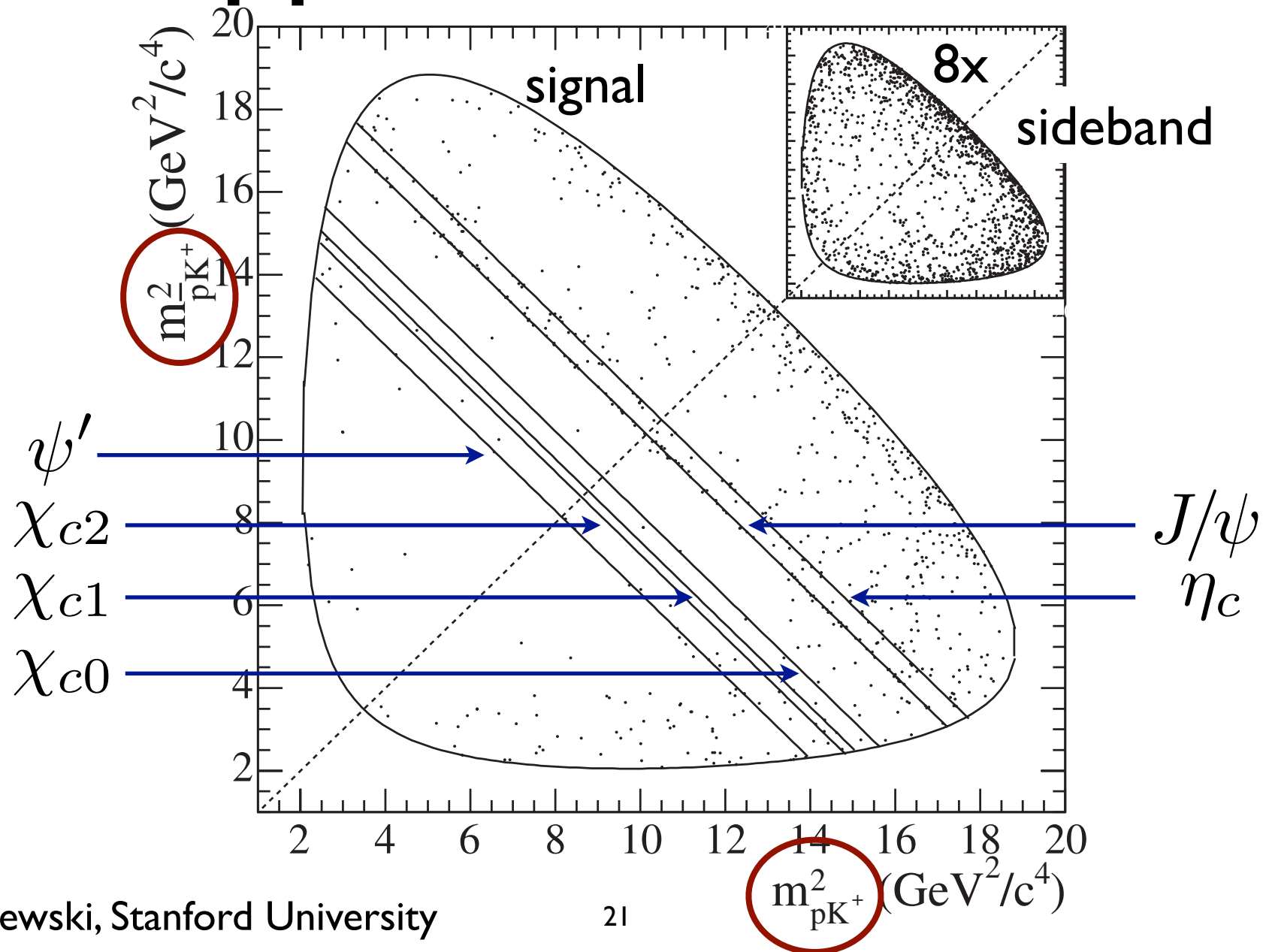
p̄K⁺ Correlation?

penguin
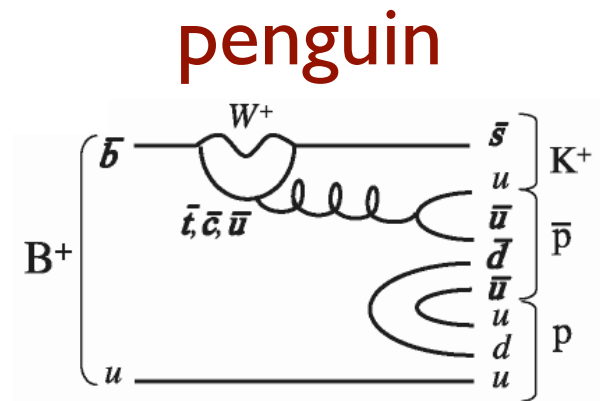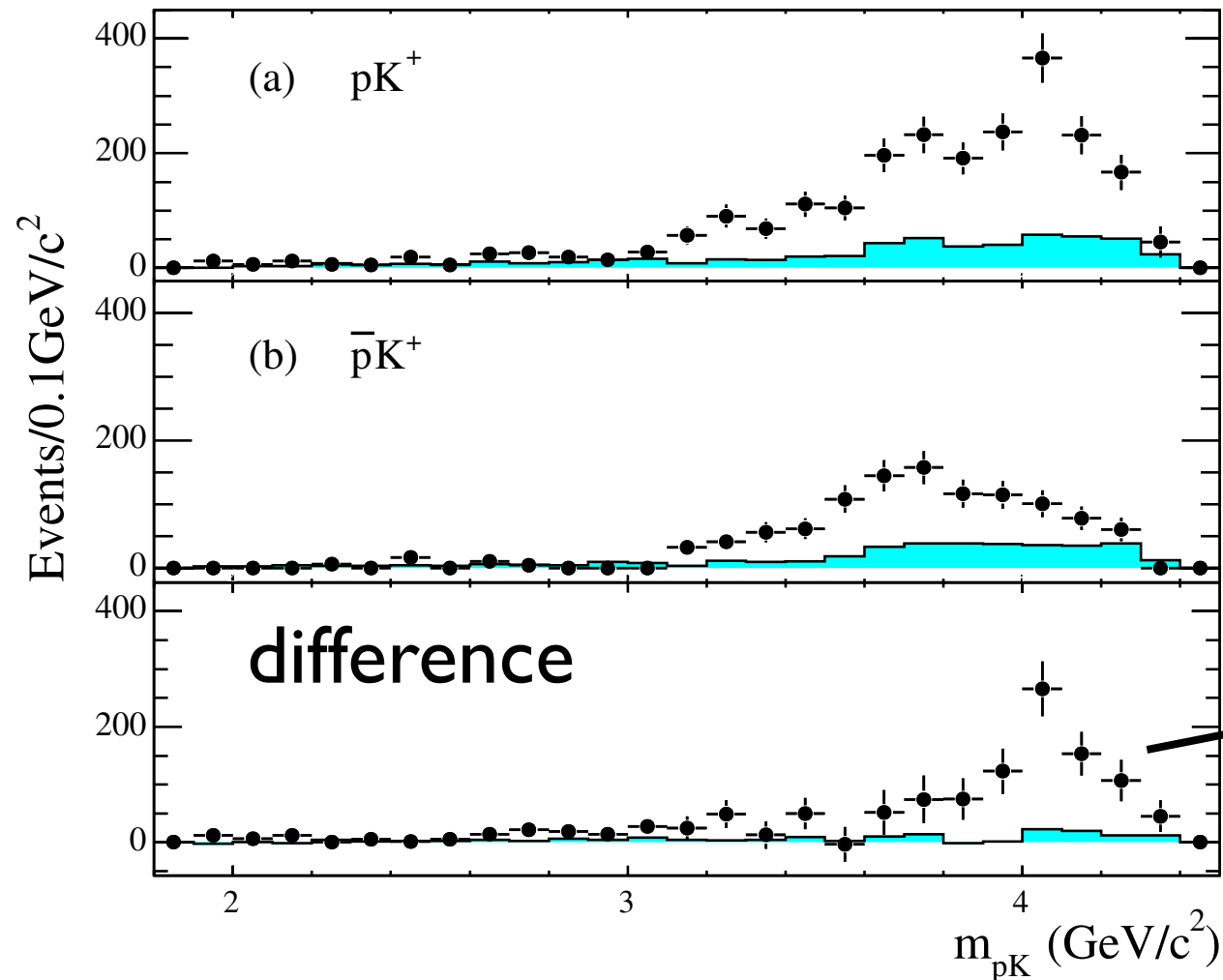
correlation between quarks in $\bar{p}$, K⁺?

Search for Exotic Baryons
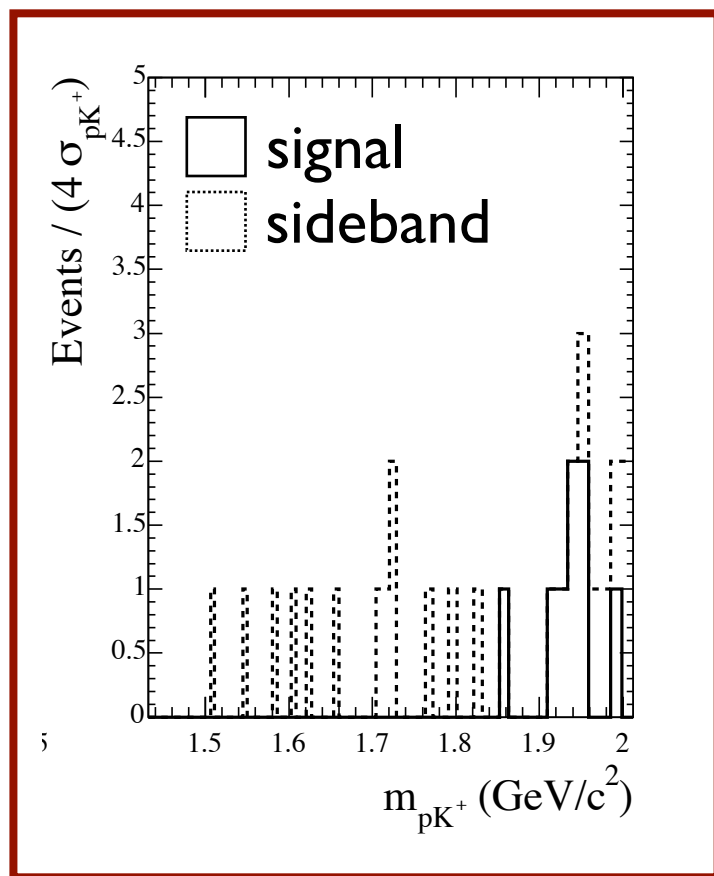
predicted in the region
$1.43 < m_{pK^+} < 1.70$ GeV/c^2

J. High Energy Phys. 05 (2004) 002
PRD **69**, 077501 (2004)
J. Exp. Theor. Phys. **97**, 433 (2003)
Ukr. Phys. J. **49**, 944 (2004)

$$\mathcal{B}\left(B^+ \rightarrow \Theta^{*++}\overline{p}\right) \times \mathcal{B}\left(\Theta^{*++} \rightarrow pK^+\right) < 1.2 \times 10^{-7}$$

- $B \rightarrow p\bar{p}K$

- $B \rightarrow D^{(*)}p\bar{p}(\pi)$

- $B \rightarrow \Lambda\bar{p}\pi$

- $B \rightarrow \Lambda_c\bar{p}(\pi)$

TM & © Nelvana

$B \to Dp\overline{p}(\pi)$ Diagrams
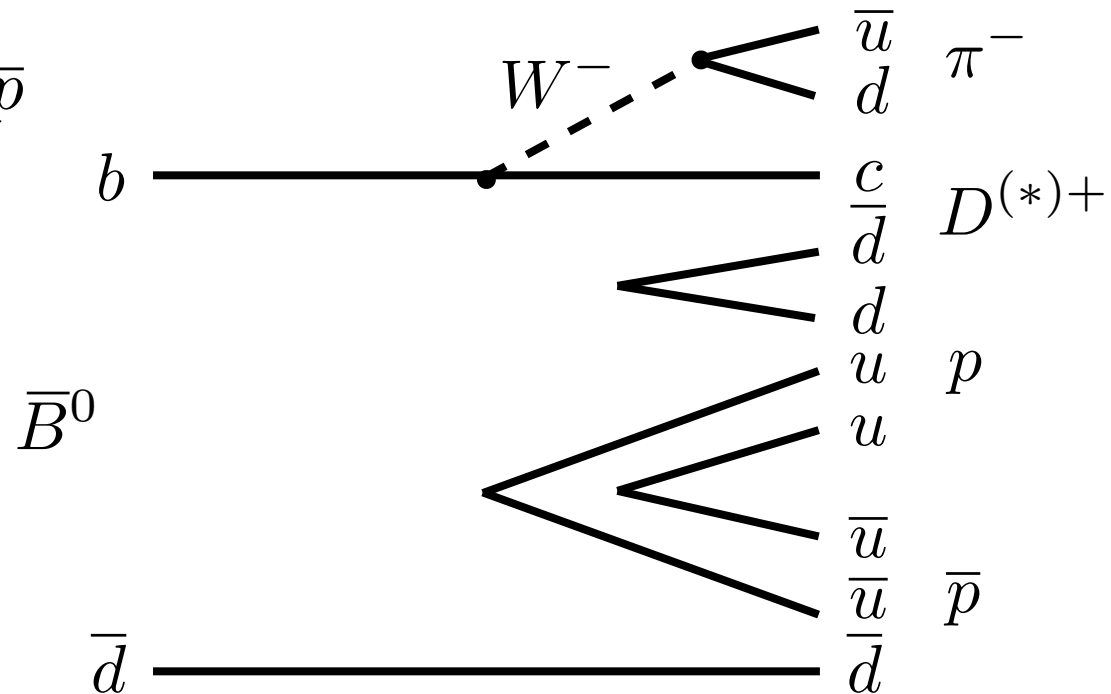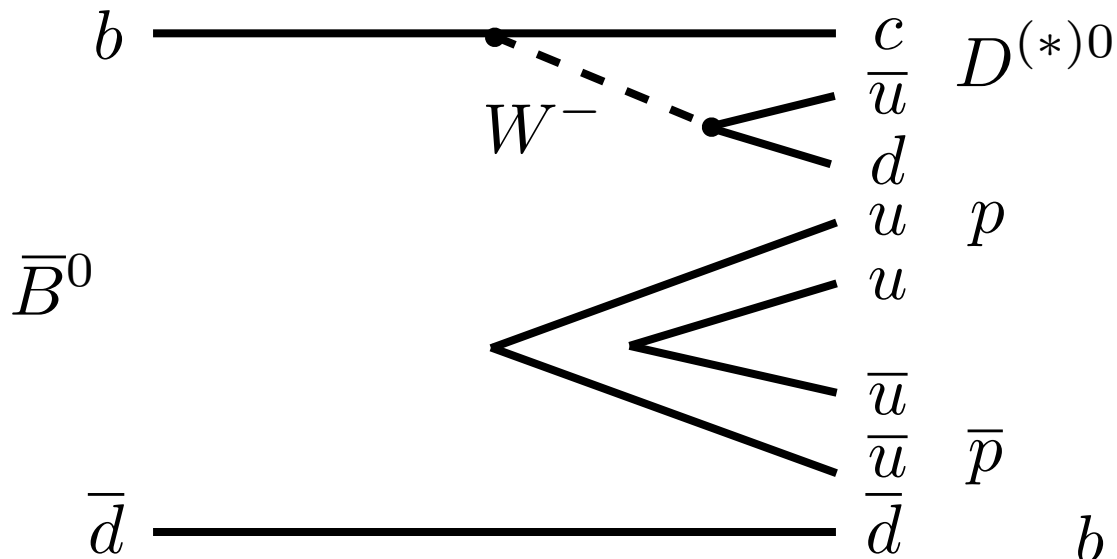
$$\mathcal{B}\left(B \longrightarrow D p \bar{p}(\pi)\right)$$

$B^0 \to \overline{D}^0 p \bar{p}$

$\overline{D}^0 \to K^+ \pi^-$
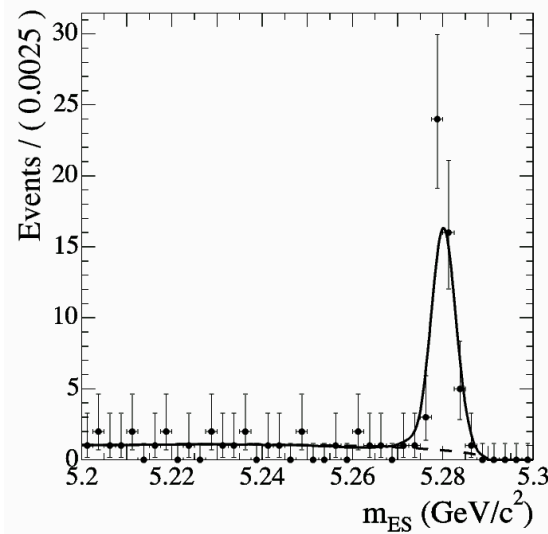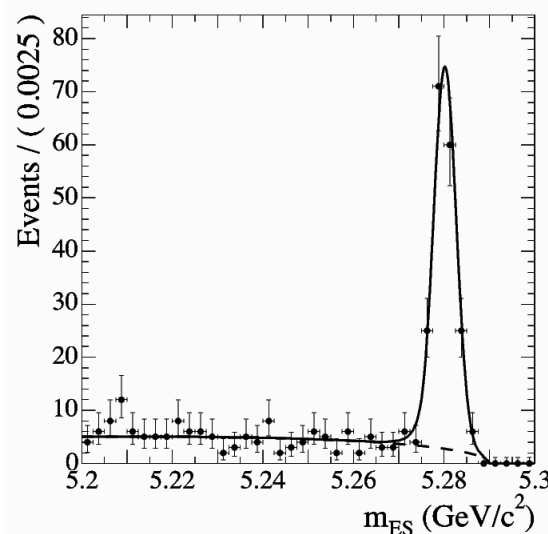
$B^0 \to \overline{D}^{*0} p \bar{p}$

$\overline{D}^{*0} \to \overline{D}^0 \pi^0$

$\overline{D}^0 \to K^+ \pi^-$

$B^0 \to D^- p \bar{p} \pi^+$

$D^- \to K^+ \pi^- \pi^-$

$B^0 \to D^{*-} p \bar{p} \pi^+$

$D^{*-} \to \overline{D}^0 \pi^-$

$\overline{D}^0 \to K^+ \pi^-$

$\mathcal{B}\left(B \longrightarrow Dp\overline{p}(\pi)\right)$

$B^0 \to \overline{D}^0 p\overline{p}$

$\overline{D}^0 \to$

$B^0 \to \overline{D}^{*0} p\overline{p}$

$\to \overline{D}^0 \pi^0$

$K^+\pi^-$

$$\mathcal{B}(B^0 \to \overline{D}^0 p\overline{p}) = (1.13 \pm 0.06 \pm 0.08) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to \overline{D}^{*0} p\overline{p}) = (1.01 \pm 0.10 \pm 0.09) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to D^- p\overline{p}\pi^+) = (3.38 \pm 0.14 \pm 0.29) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to D^{*-} p\overline{p}\pi^+) = (4.81 \pm 0.22 \pm 0.44) \times 10^{-4}$$

$B^0 \to D^- p\overline{p}\pi^+$

$D^- \to K^+\pi^-\pi^-$

$\to D^{*-} p\overline{p}\pi^+$

$D^{*-} \to \overline{D}^0 \pi^-$

$\overline{D}^0 \to K^+\pi^-$

p̄p Threshold Enhancement

all 4 modes,
phase-space
corrected

$B^0 \to \overline{D}^0 p\overline{p}$
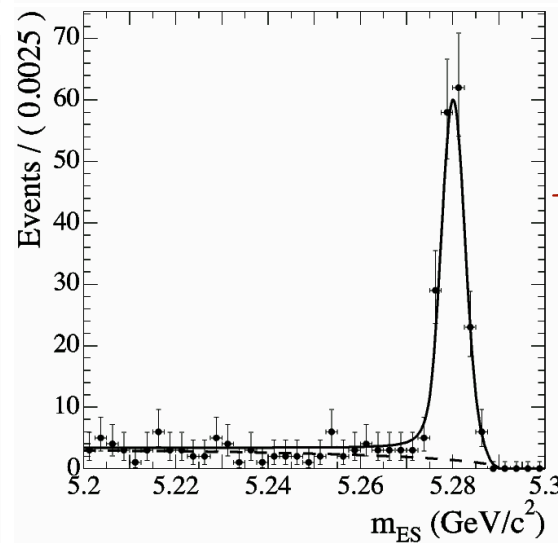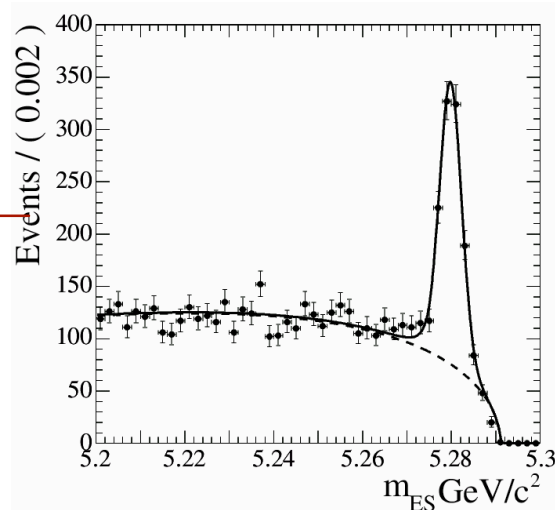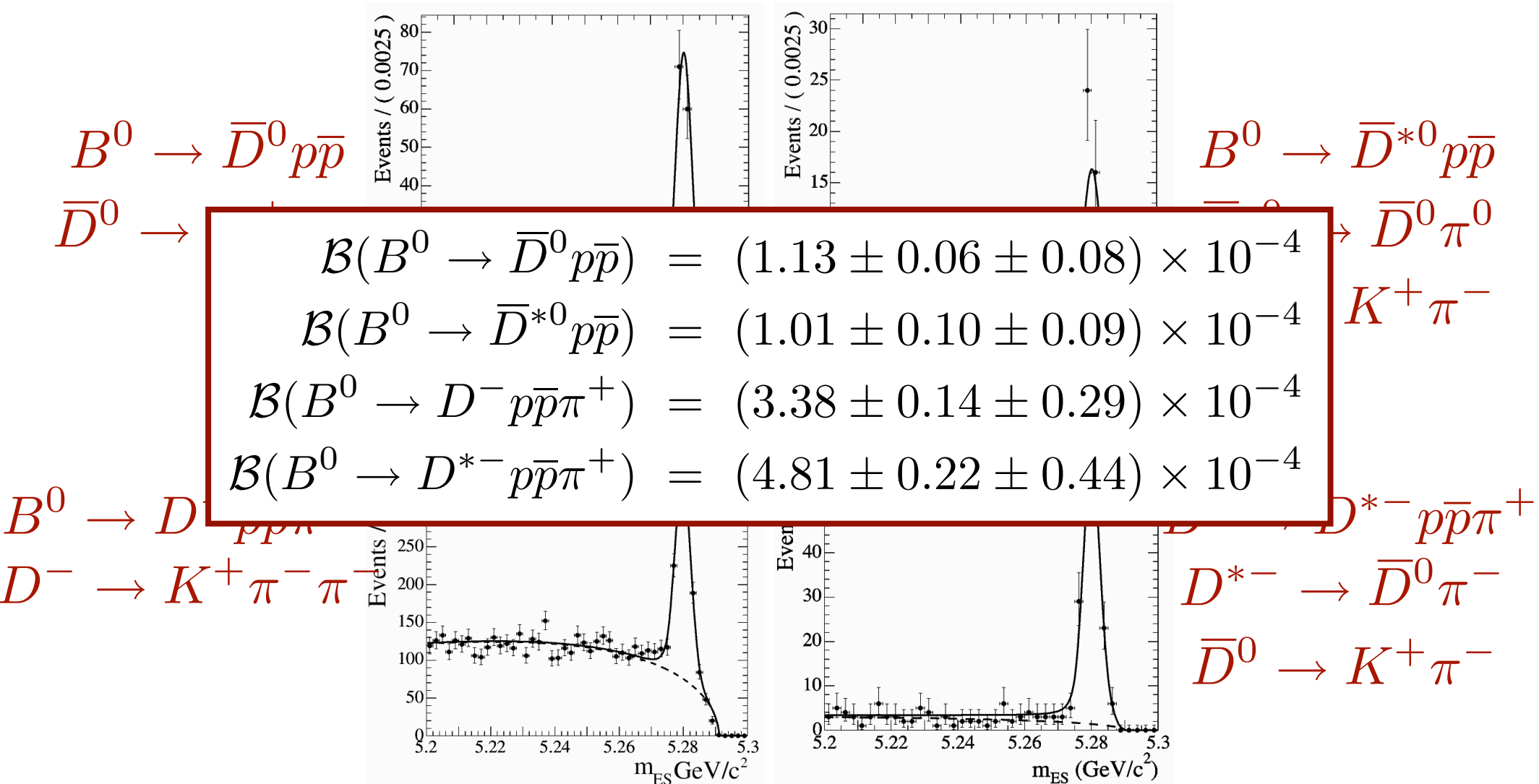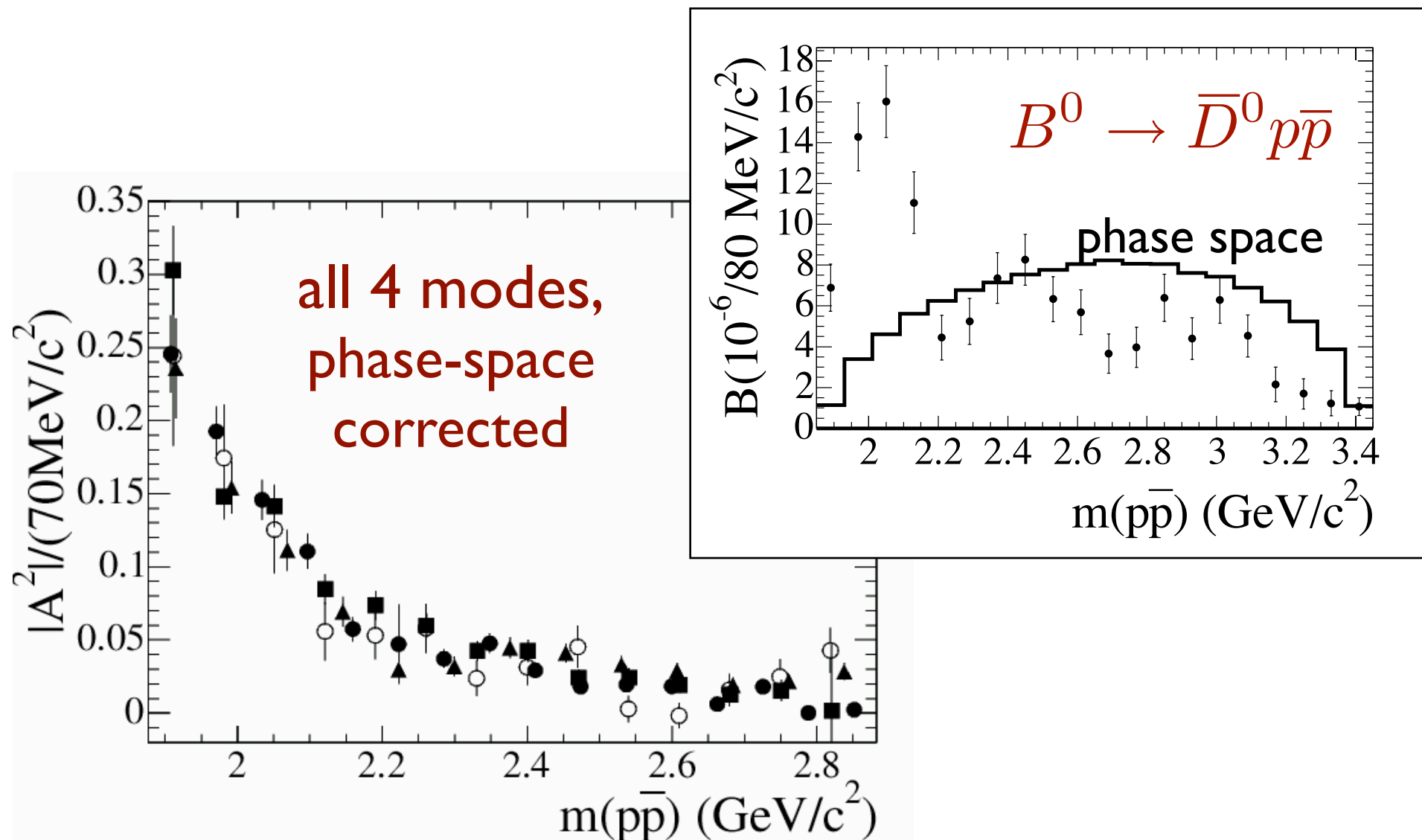
phase space

p̄p Threshold Enhancement

Comparison, phase-space corrected

- **B → Dpp̄(π)** (4 modes)
- ○ B → pp̄K
- □ e⁺e⁻ → pp̄Y

BABAR: PRD **73**, 012005 (2006)

Search for Exotic Baryons

$$\Theta_c \begin{pmatrix} u\ u \\ d\ d \\ \bar{c} \end{pmatrix}$$
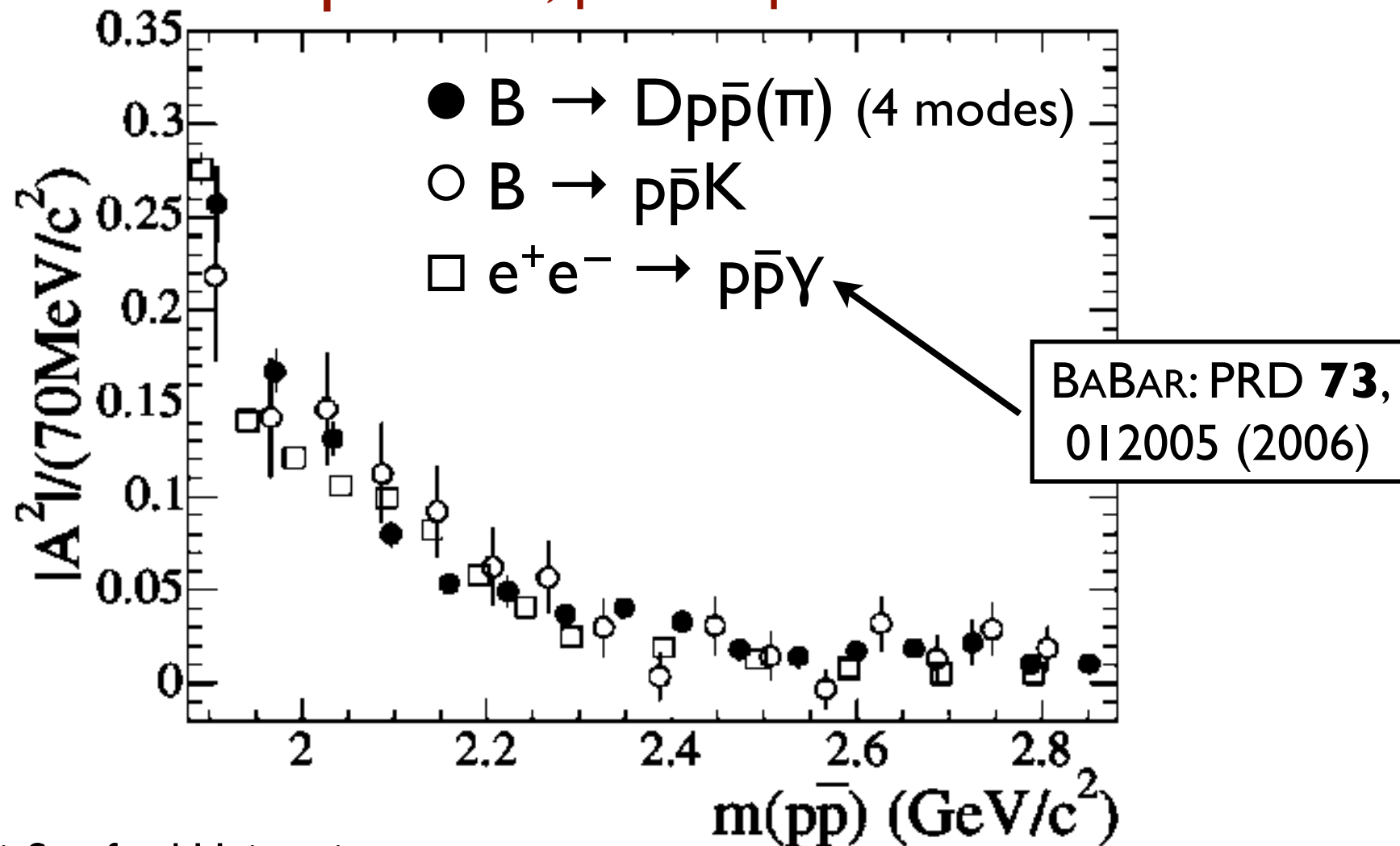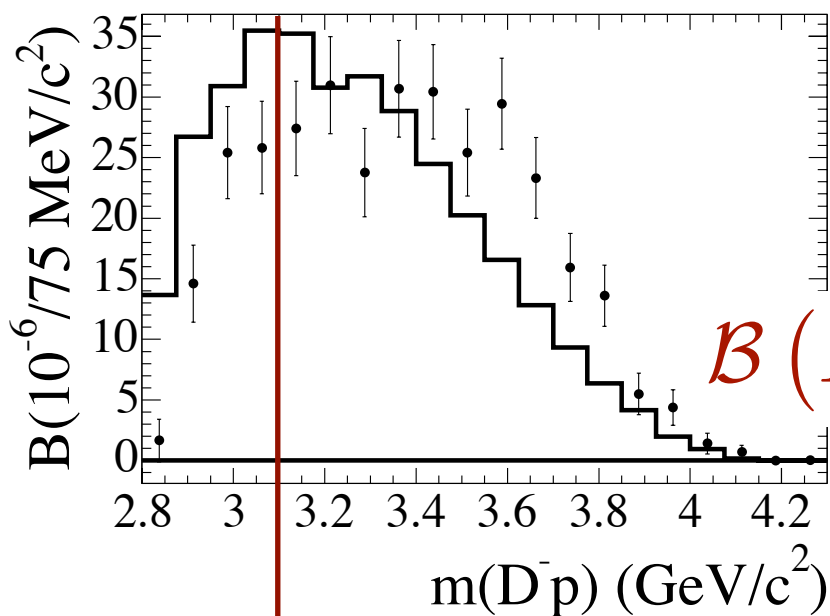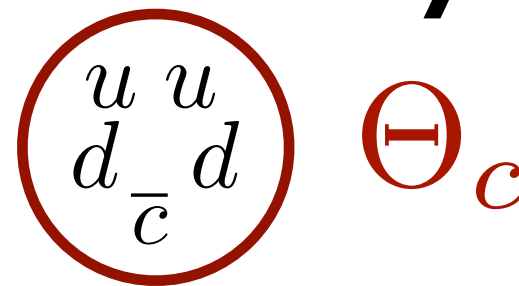
$$\mathcal{B}\left(B^0 \to \Theta_c \bar{p}\pi^+\right) \times \mathcal{B}\left(\Theta_c \to D^- p\right)$$

$$< 9 \times 10^{-6}$$
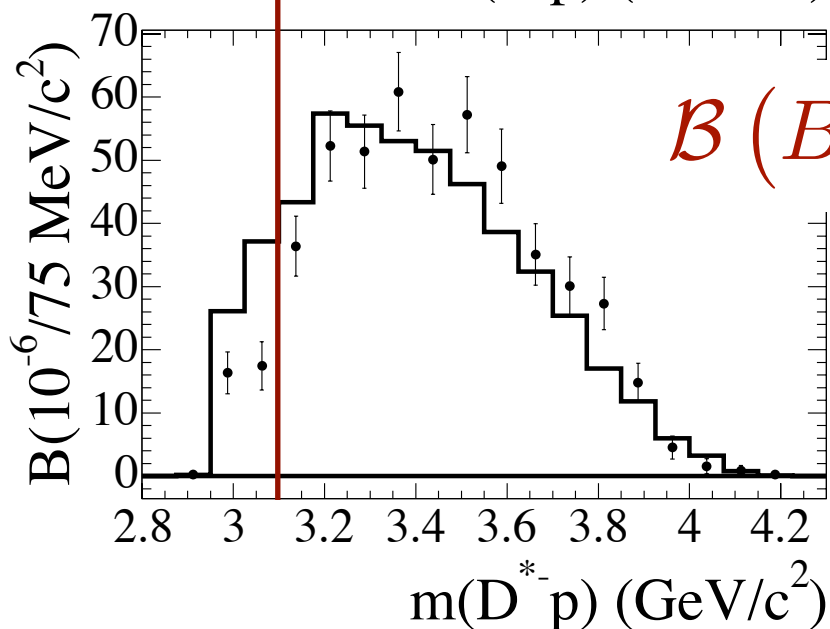
$$\mathcal{B}\left(B^0 \to \Theta_c \bar{p}\pi^+\right) \times \mathcal{B}\left(\Theta_c \to D^{*-} p\right)$$

$$< 14 \times 10^{-6}$$

H1 Collaboration:
Evidence for Θ_c with mass = 3.099 ± 0.003 GeV and width =12 ± 3 MeV
PLB **588**,17 (2004)

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- $B \to p\bar{p}K$

- $B \to D^{(*)}p\bar{p}(\pi)$

- $B \to \Lambda\bar{p}\pi$

- $B \to \Lambda_c\bar{p}(\pi)$

TM & © Nelvana

$\overline{B}^0 \rightarrow \Lambda\overline{p}\pi^+$ Diagrams

tree

penguin

tree

$$\overline{B}^0 \longrightarrow \Lambda \overline{p} \pi^+$$

$$N_{\text{sig}} = 74^{+12}_{-11}$$
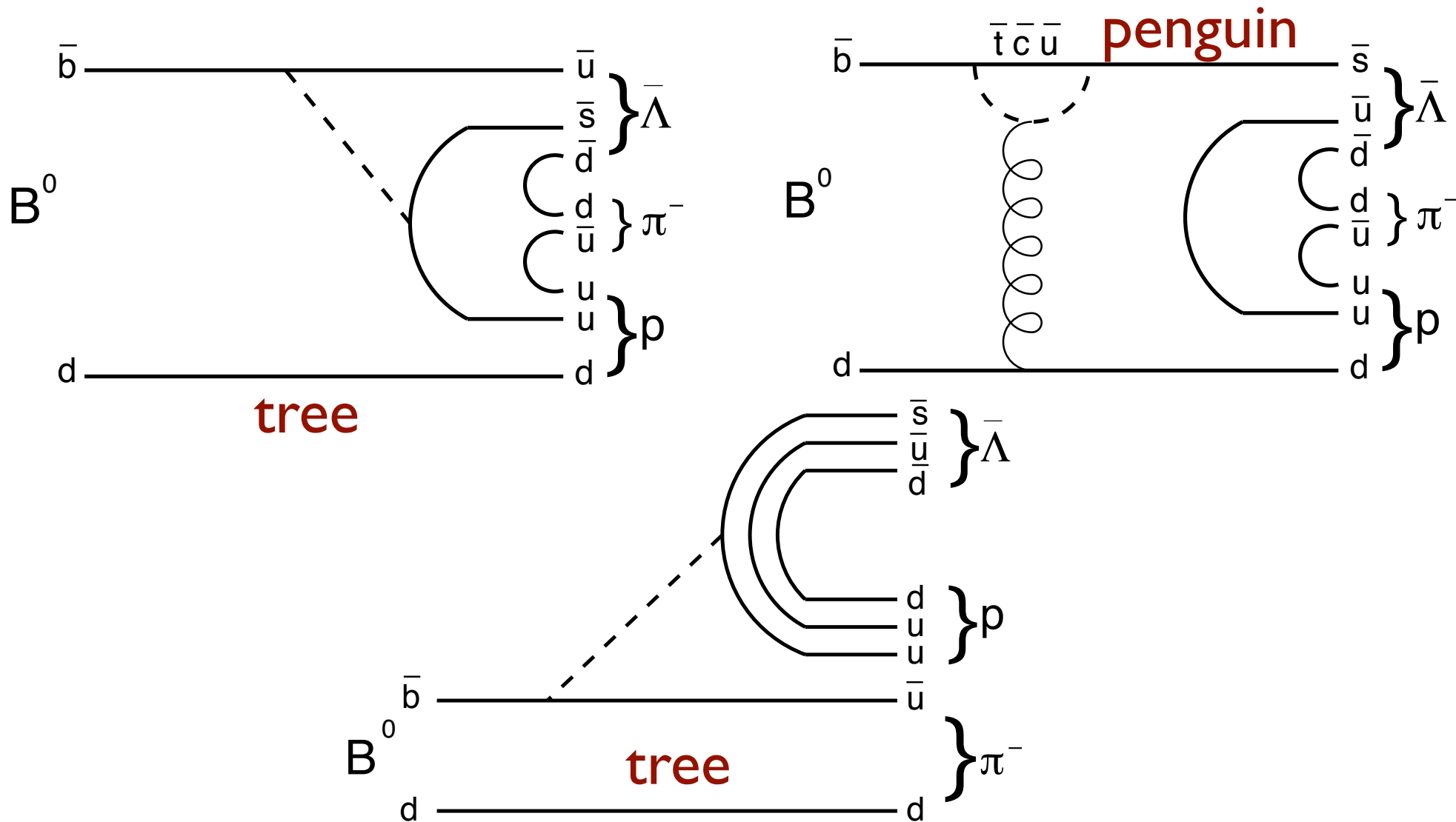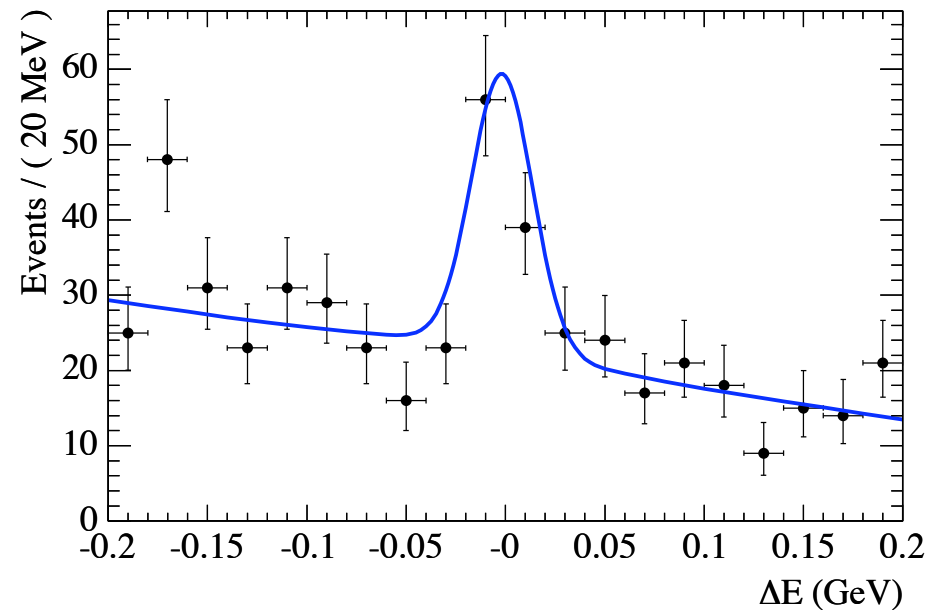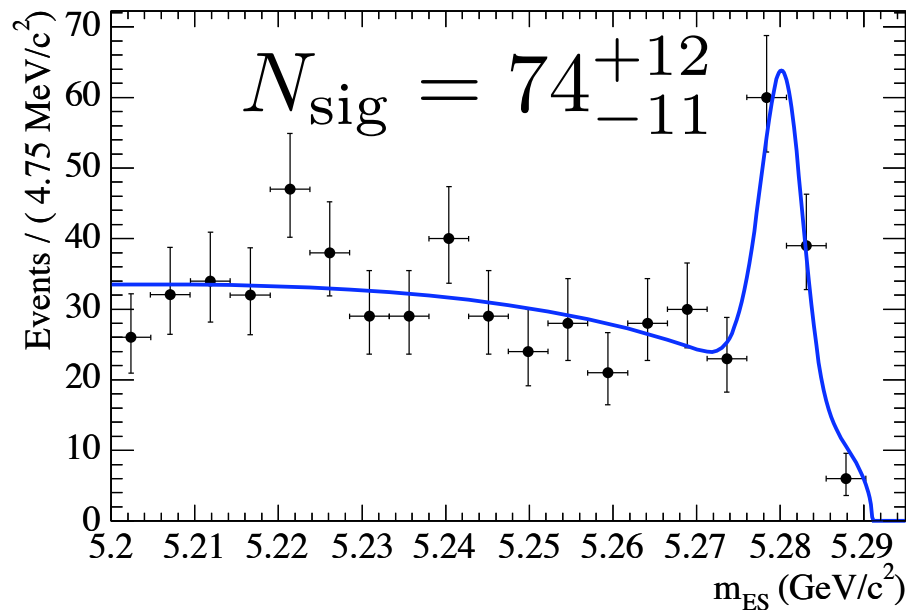
$$\mathcal{B}\left(\overline{B}^0 \to \Lambda \overline{p} \pi^+\right) = (3.3 \pm 0.5 \pm 0.3) \times 10^{-6}$$

$\Lambda\bar{p}$ Threshold Enhancement
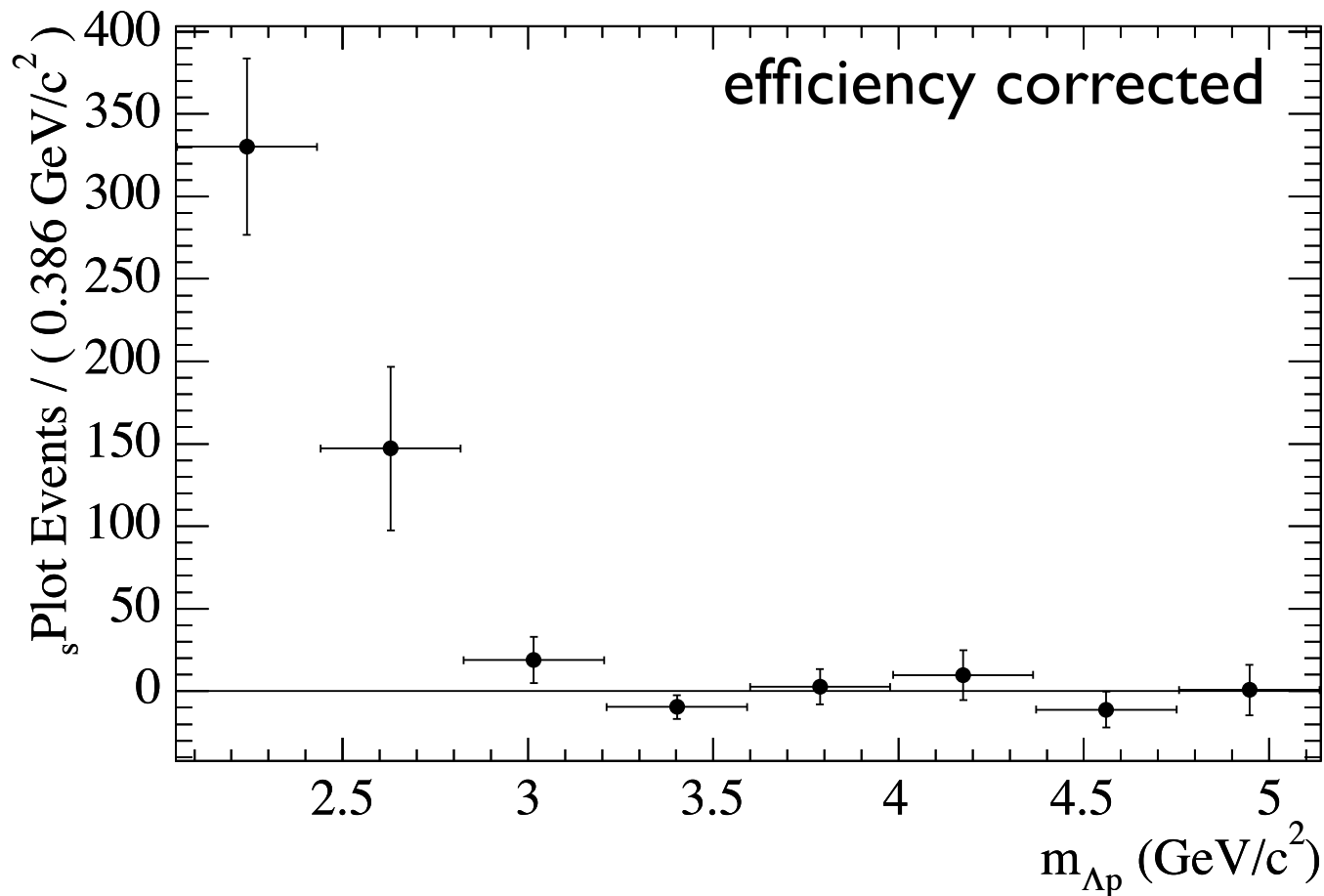
- $B \to p\overline{p}K$

- $B \to D^{(*)}p\overline{p}(\pi)$

- $B \to \Lambda\overline{p}\pi$

- $B \to \Lambda_c\overline{p}(\pi)$
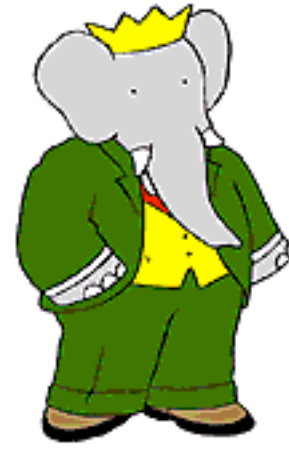
TM & © Nelvana

$B \longrightarrow \Lambda_c \bar{p}\,(\pi)$ Diagrams
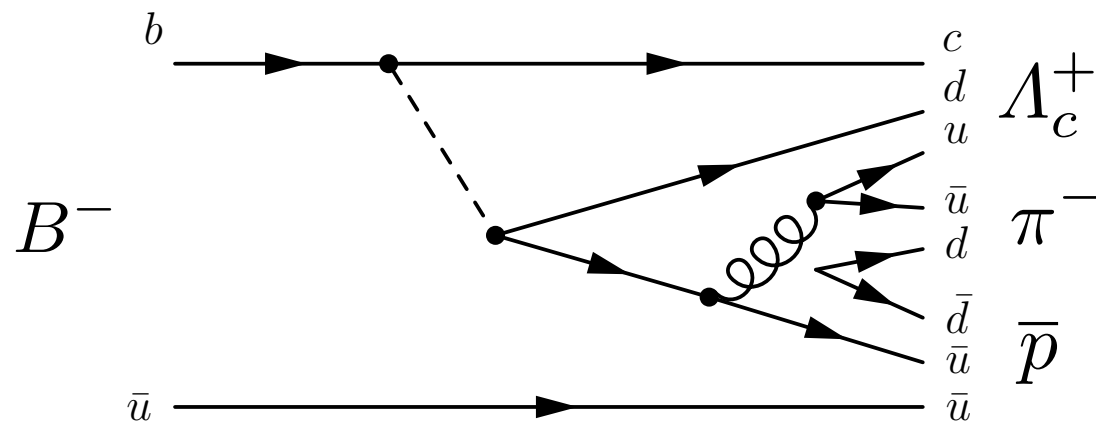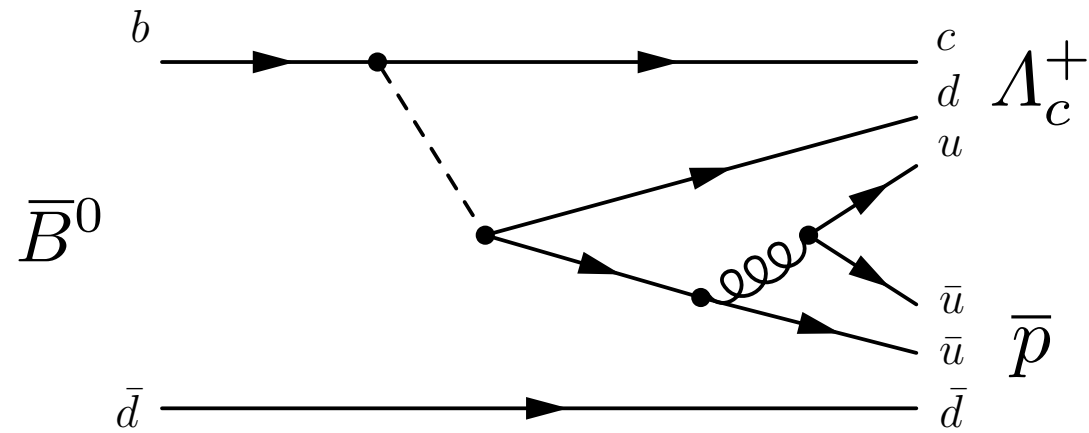
Reconstruction

- Reconstruct Λ_c in 5 decay modes; constrain $m(\Lambda_c)$ to $m(\Lambda_c)_{PDG}$

- Decay modes:

$$\Lambda_c^+ \rightarrow pK^-\pi^+$$
$$\Lambda_c^+ \rightarrow pK_S^0$$
$$\Lambda_c^+ \rightarrow pK_S^0\pi^+\pi^-$$
$$\Lambda_c^+ \rightarrow \Lambda\pi^+$$
$$\Lambda_c^+ \rightarrow \Lambda\pi^+\pi^-\pi^+$$

μ **= 2,286.0 $\pm$ 0.1 MeV**

σ **= 5.3 $\pm$ 0.6 MeV**

data

232M B$\bar{\text{B}}$ pairs
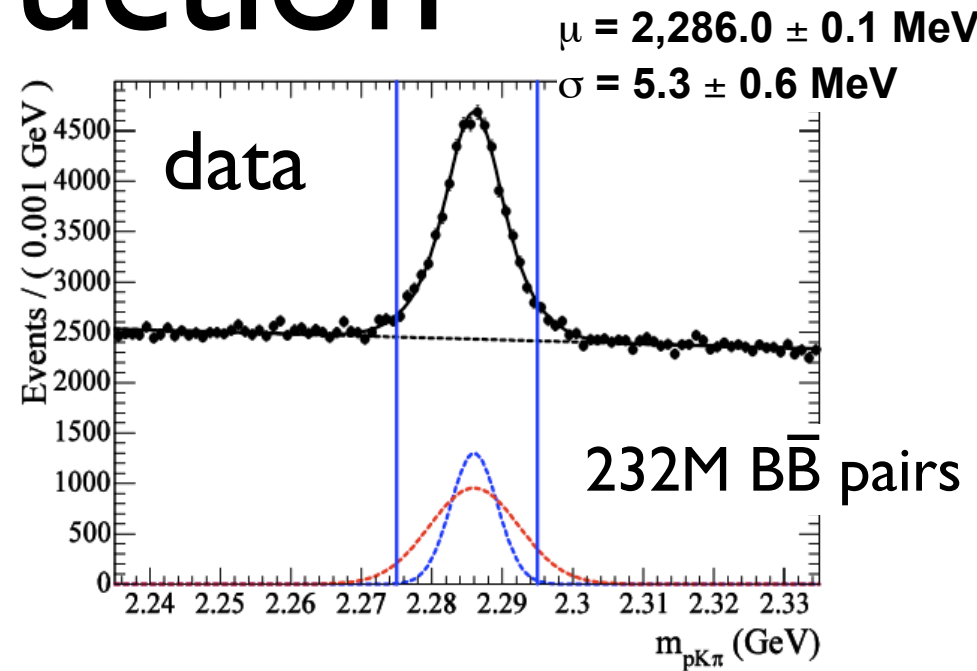
Reconstruction

- Reconstruct Λ_c in 5 decay modes; constrain $m(\Lambda_c)$ to $m(\Lambda_c)_{PDG}$

- Reconstruct B candidate

data

232M B$\bar{\text{B}}$ pairs

$$\overline{B}^0 \rightarrow \Lambda_c^+ \overline{p}$$
signal MC
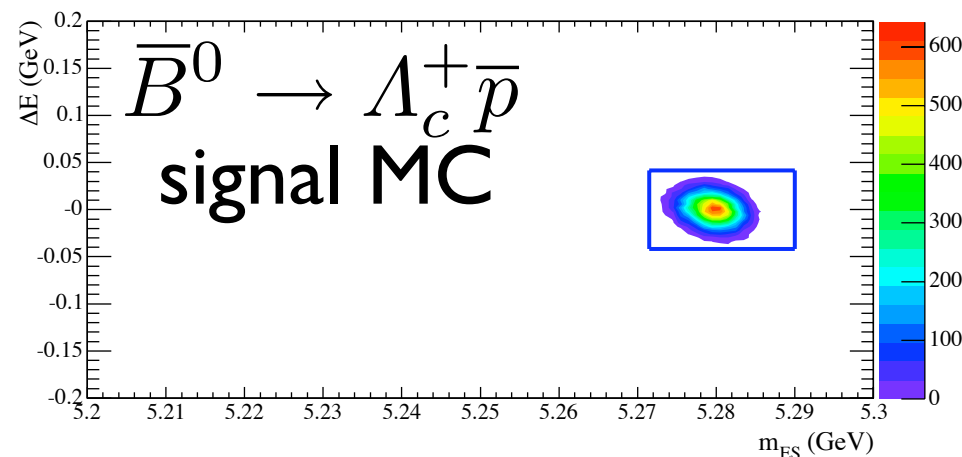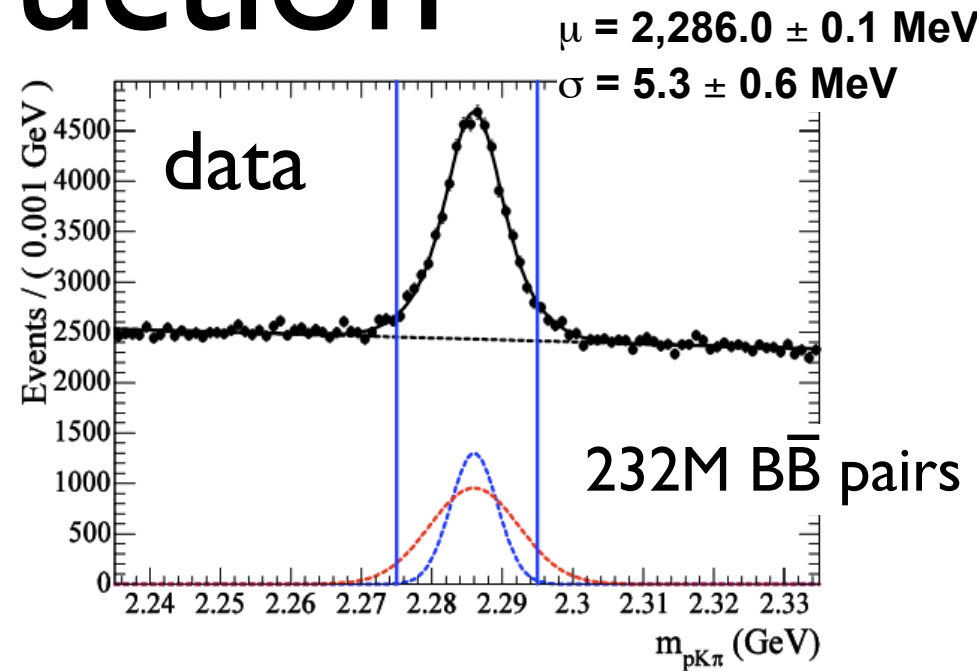
Blind Analysis

- Perform optimization of $S/\sqrt{S+B}$ using sideband data and signal MC samples

- Investigate backgrounds, determine fit strategy, validate fit before unblinding

- Can perform full fit to estimate background levels (signal region cut out of fit)

B^0 candidates
232M $B\bar{B}$ pairs

Unblinded Results

$\overline{B}^0 \to \Lambda_c^+ \overline{p}$

BABAR preliminary
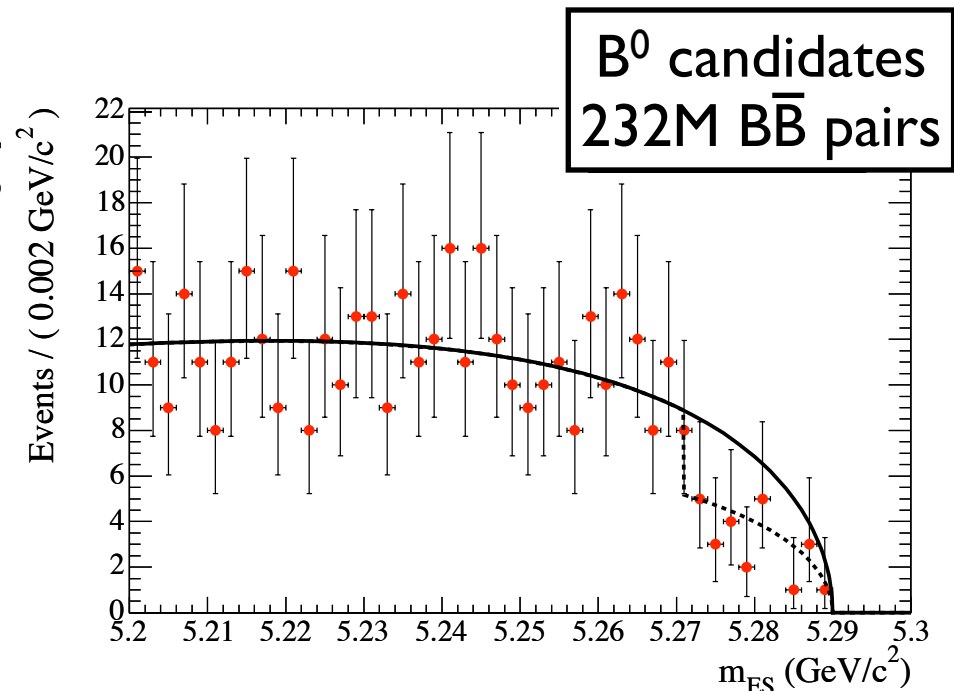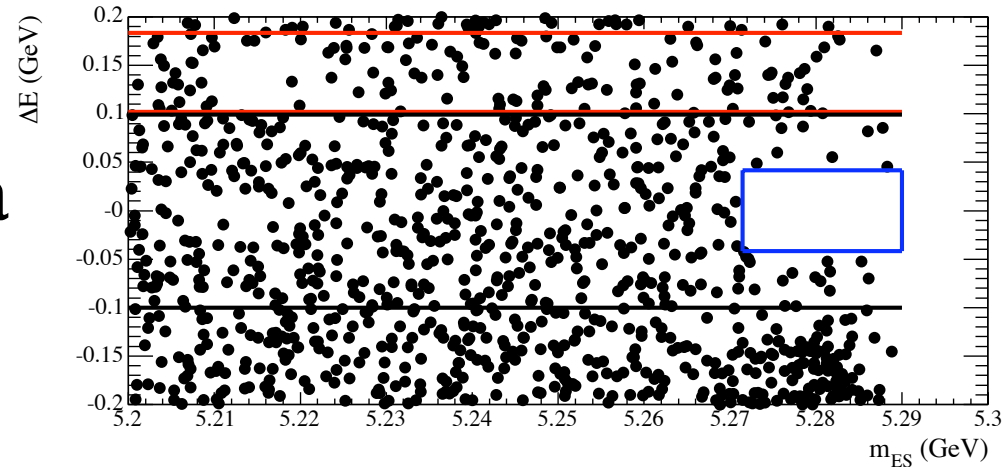
2-D Fit
232M B$\overline{\text{B}}$ pairs
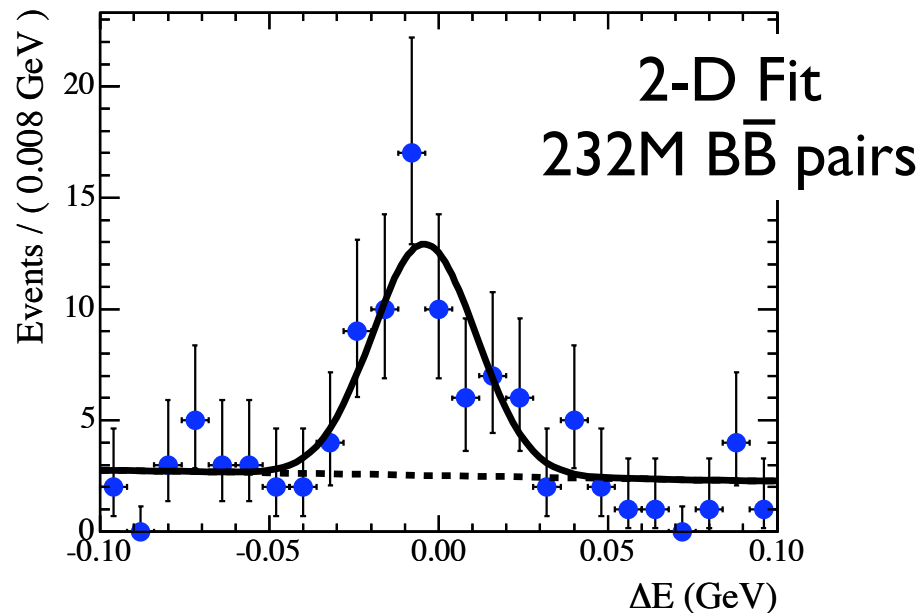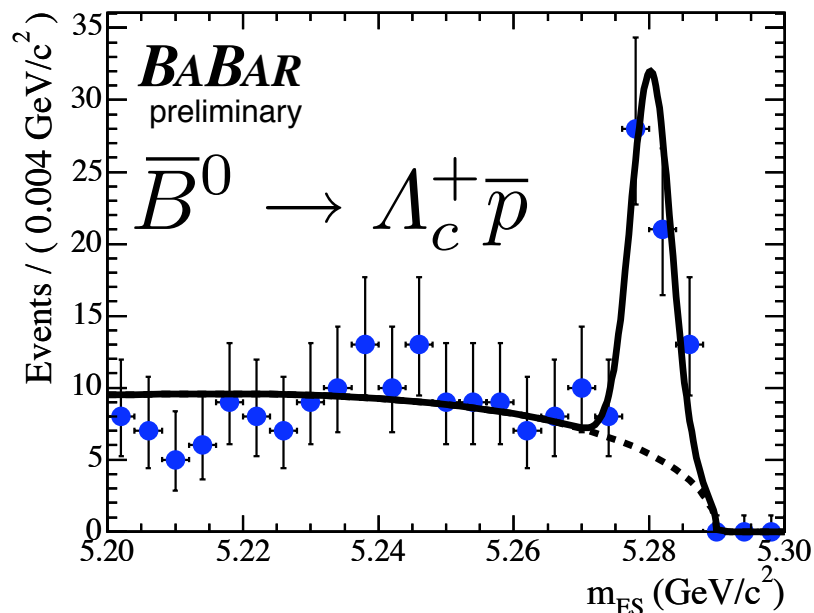
Mode	Signal yield	$\varepsilon_{\text{(eff)}}$	$\mathcal{B}$
$\overline{B}^0 \to \Lambda_c^+ \overline{p}$	50 ± 8	20.2%	$(2.15 \pm 0.36 \pm 0.13 \pm 0.56) \times 10^{-5}$
$B^- \to \Lambda_c^+ \overline{p}\pi^-$	571 ± 34	14.2%	$(3.53 \pm 0.18 \pm 0.31 \pm 0.92) \times 10^{-4}$

Results were presented at ICHEP 2006
hep-ex/0706055

$B^- \to \Lambda_c^+ \overline{p}\pi^-$

BABAR preliminary

2-D Fit
232M B$\overline{\text{B}}$ pairs

40

$$\frac{\mathcal{B}\left(B^{-} \to \Lambda_c^{+}\overline{p}\pi^{-}\right)}{\mathcal{B}\left(\overline{B}^{0} \to \Lambda_c^{+}\overline{p}\right)} = 16.4 \pm 2.9 \pm 1.4$$

41
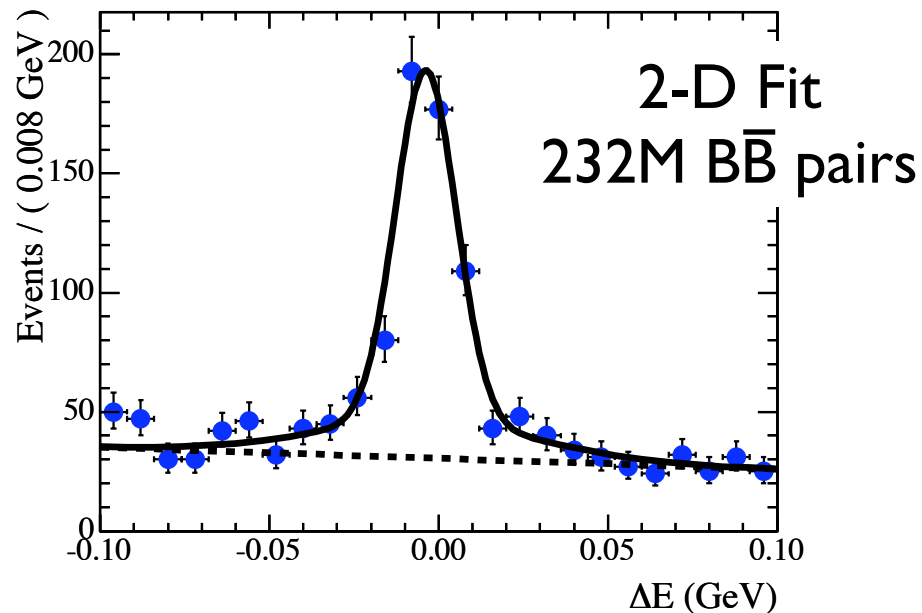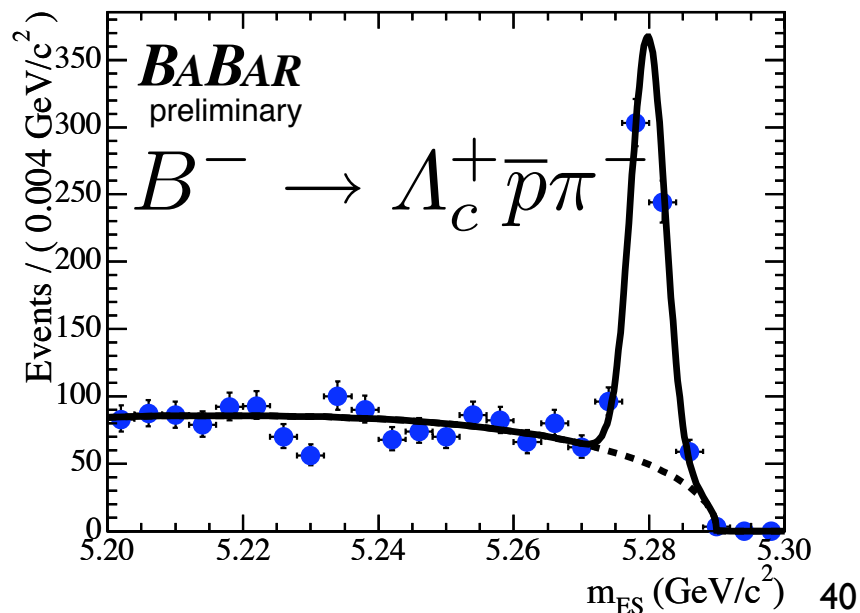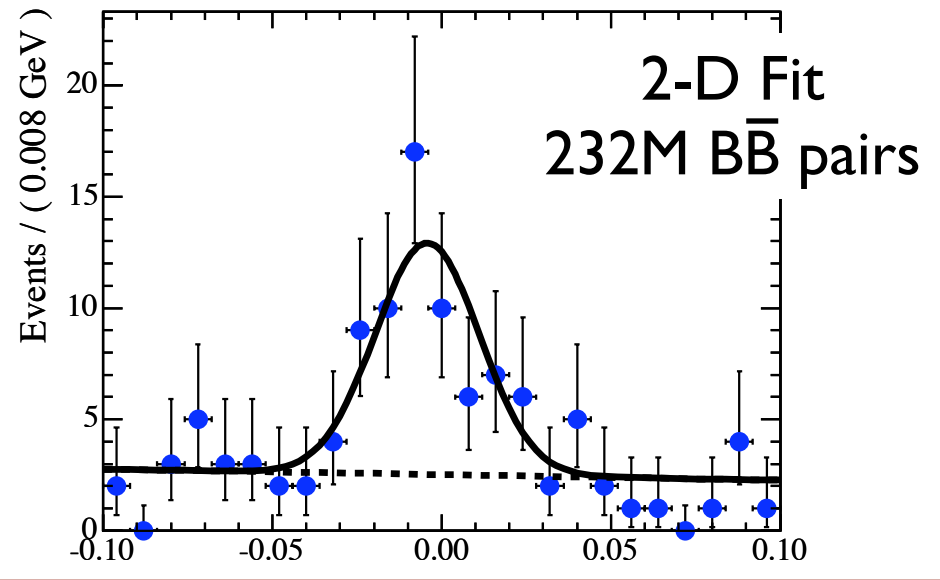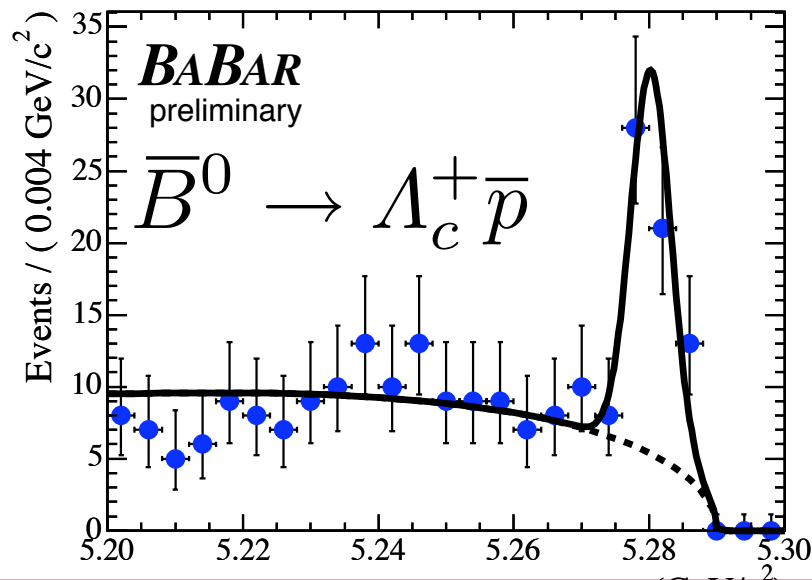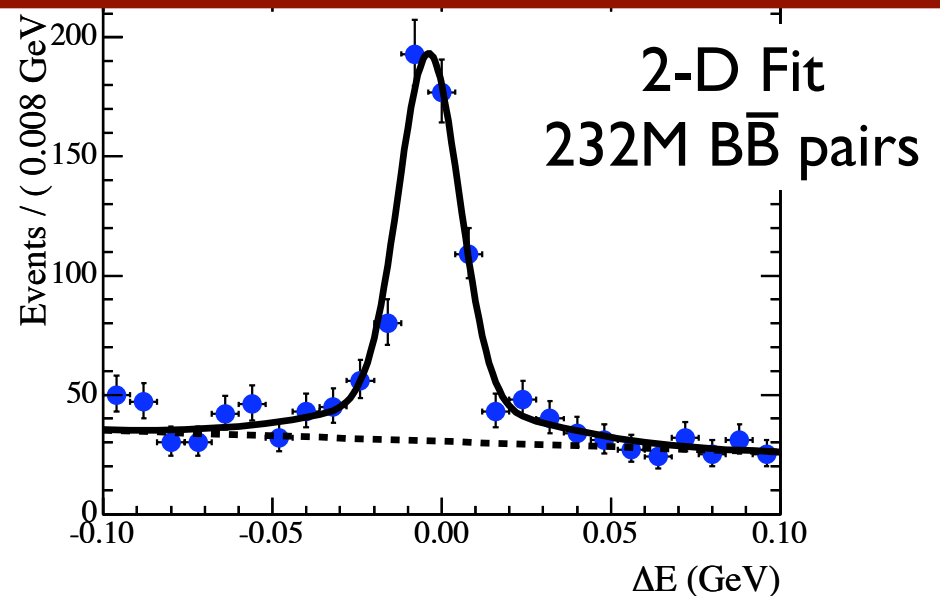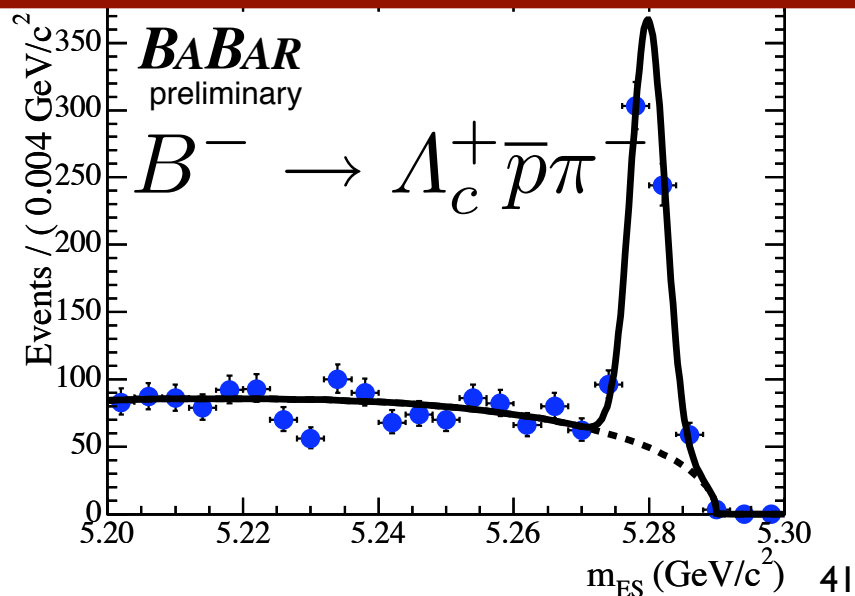
Binned Efficiency Correction
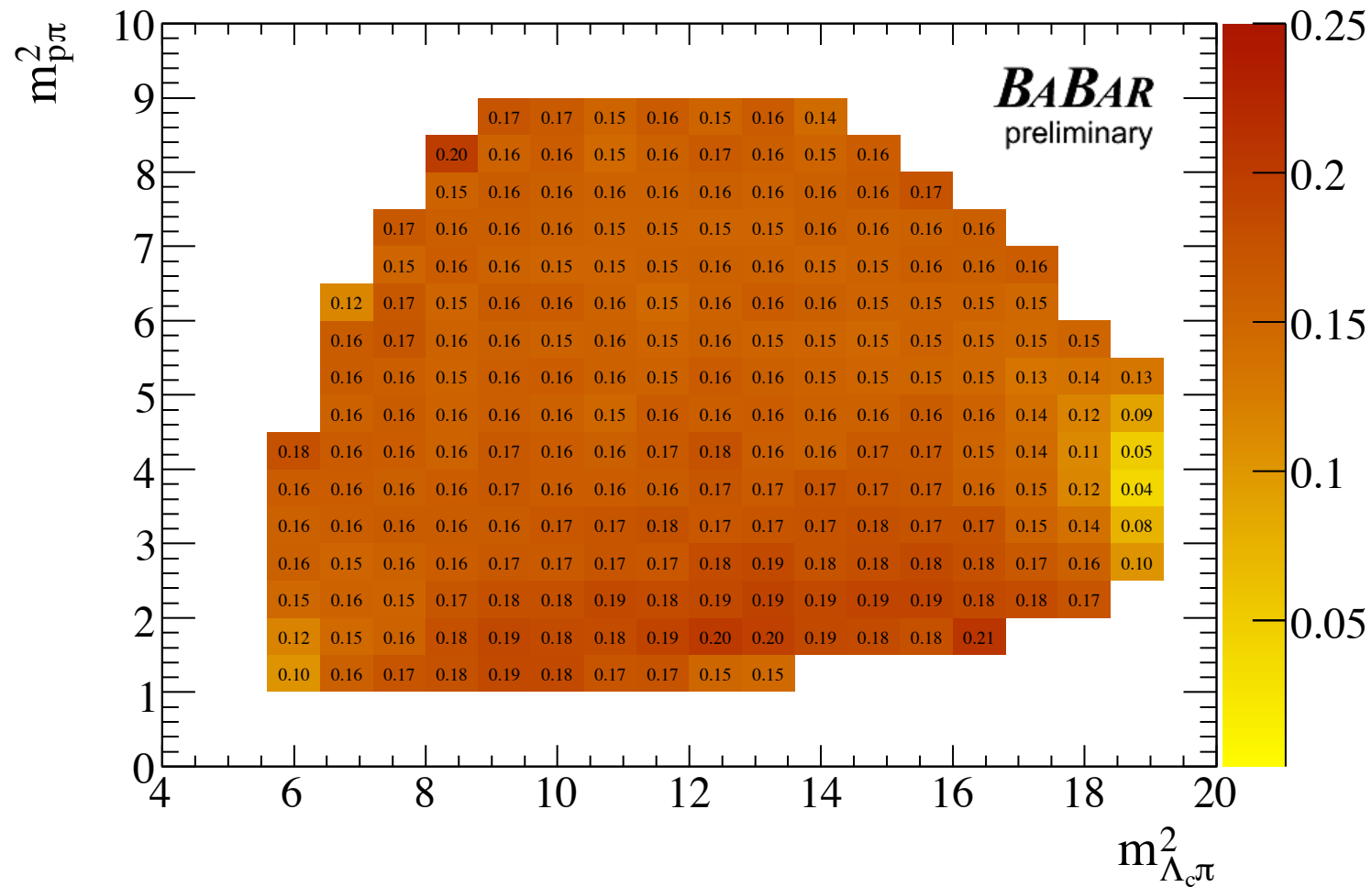
$B^- \rightarrow \Lambda_c^+ \overline{p} \pi^-$
Threshold Enhancement
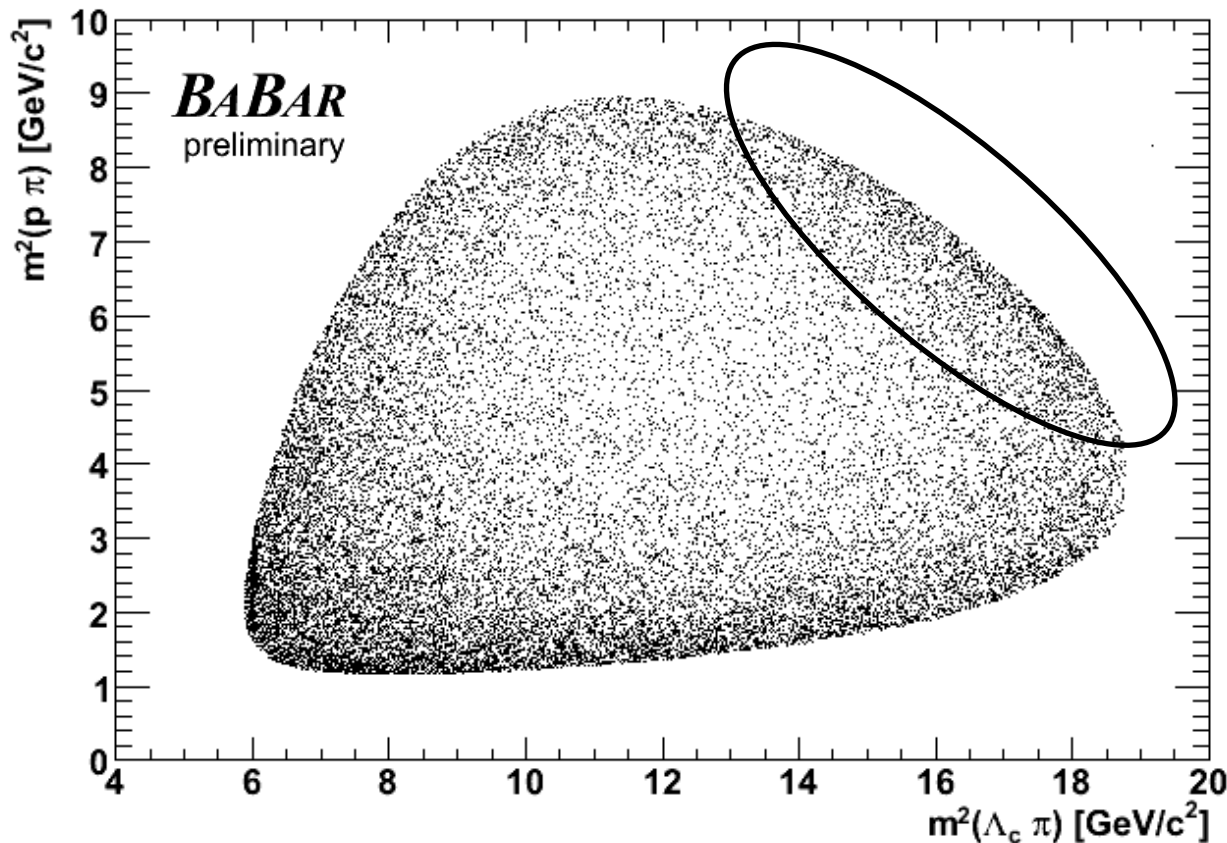
$_s\mathcal{P}lot$
weighting technique
separates signal &
background

M. Pivk and F.R. LeDiberder,
NIM **A555**, 356 (2005).

$B^- \rightarrow \Lambda_c^+ \overline{p} \pi^-$
Threshold Enhancement
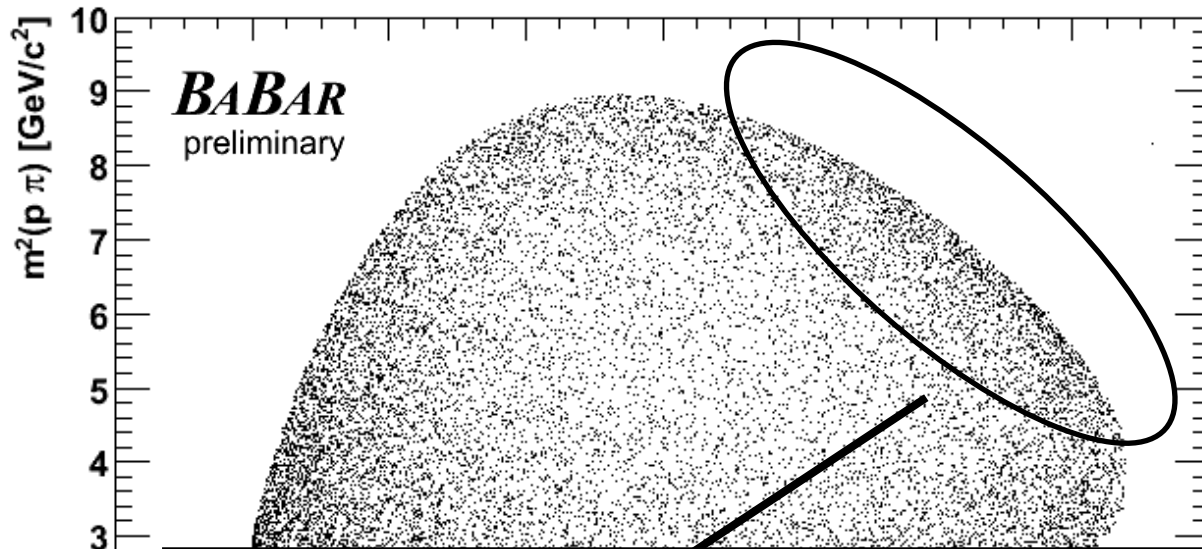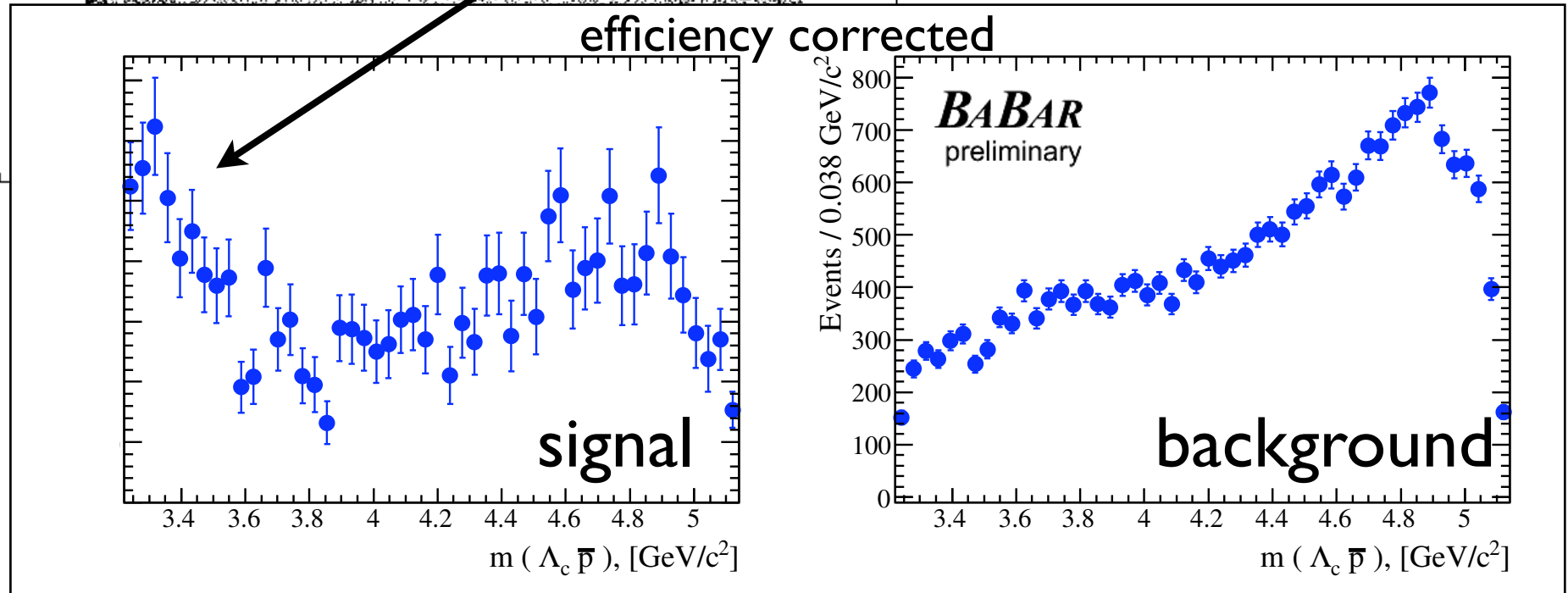
$_s\mathcal{P}lot$
weighting technique
separates signal &
background

$B^- \rightarrow \Lambda_c^+ \overline{p} \pi^-$
Resonant Substructure
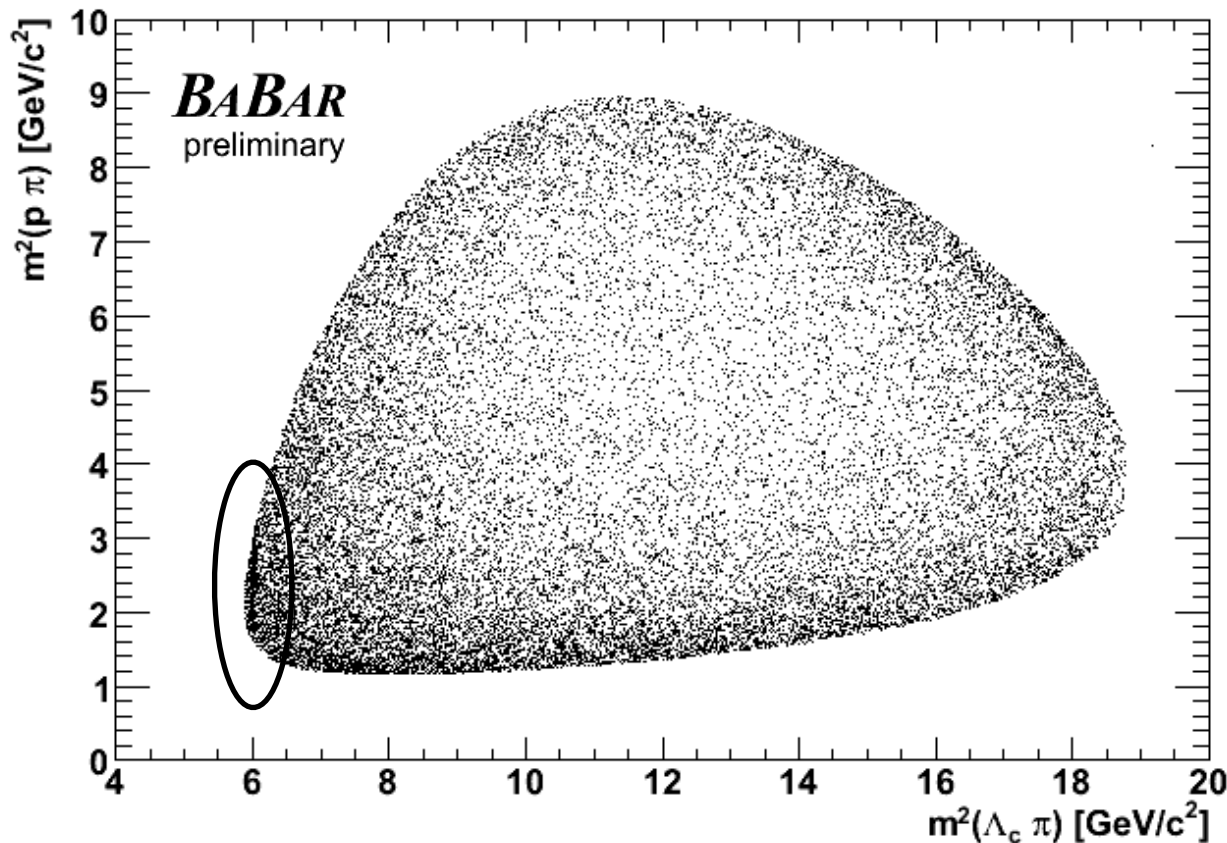
$${}_s\mathcal{P}lot$$

weighting technique separates signal & background

M. Pivk and F.R. LeDiberder, NIM **A555**, 356 (2005).

$B^- \rightarrow \Lambda_c^+ \overline{p} \pi^-$
Resonant Substructure

$_s\mathcal{P}lot$
weighting technique
separates signal &
background

efficiency
corrected

$\Sigma_c(2455)^0$
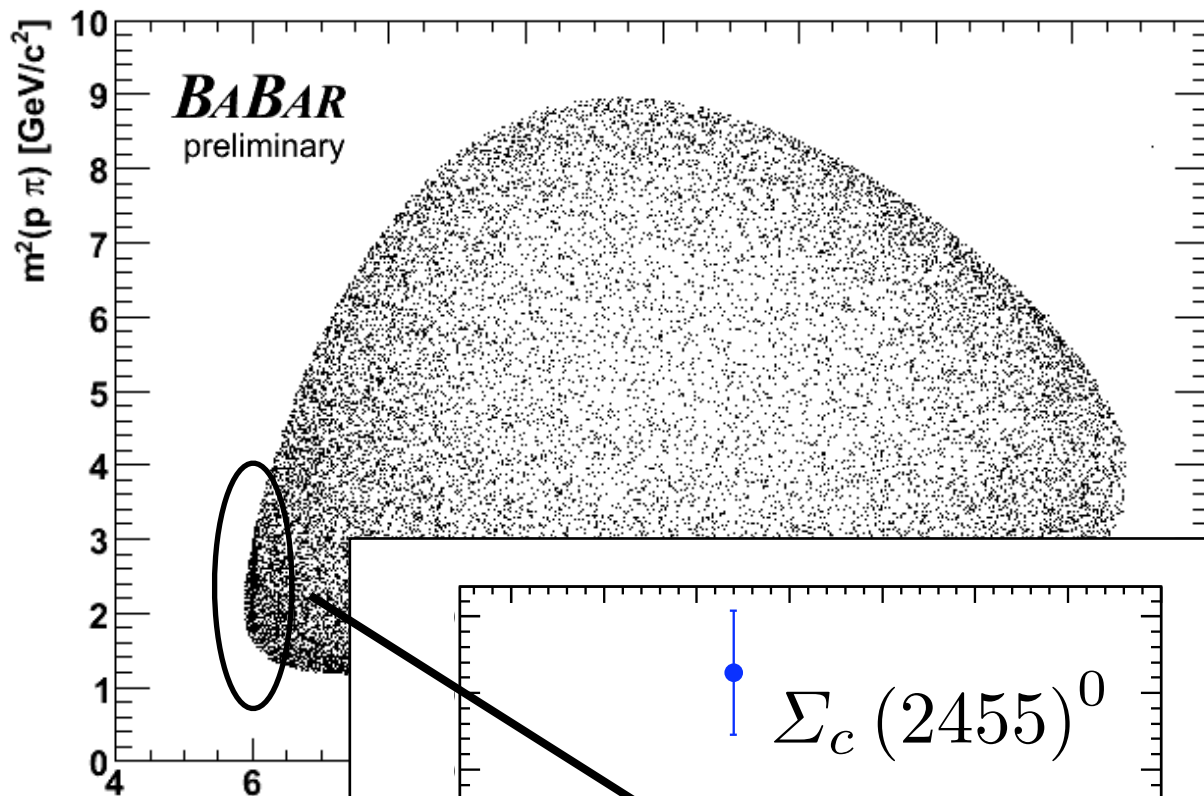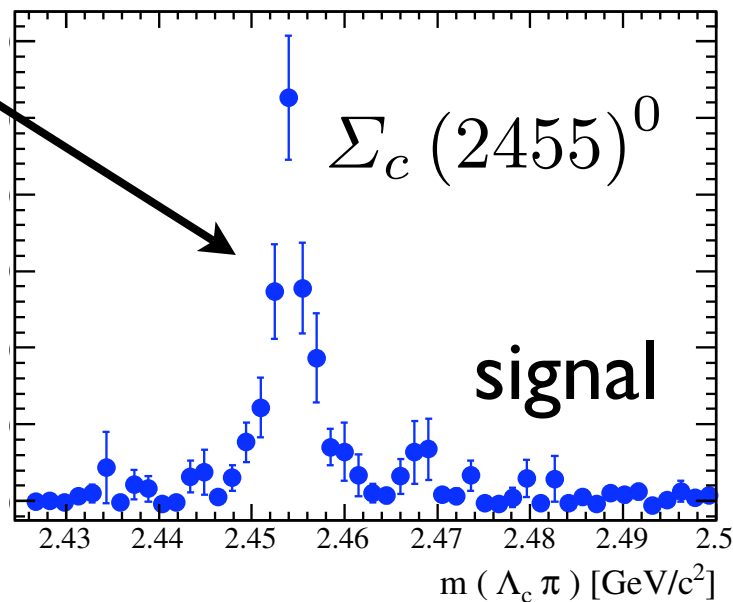
signal

background
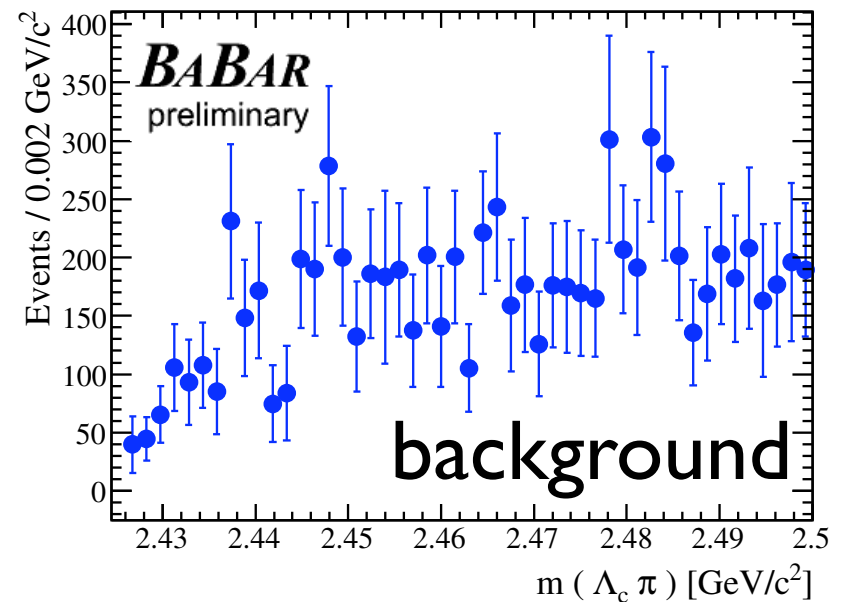
Baryon Spin

- Most baryon J^P quantum numbers have not been measured
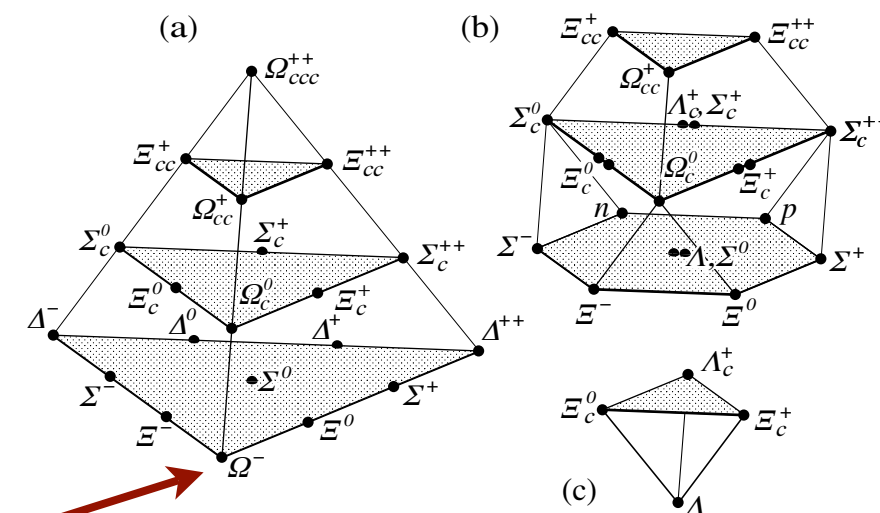
Exception:
$J(\Omega^-) = 3/2$

Figure 2: SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) decuplet on the lowest level. (b) The $20'$-plet with an SU(3) octet on the lowest level. (c) The $\overline{4}$-plet.

PDG 2006

Spin measurement of Ω^- from $\Xi_c^0 \to \Omega^- K^+$, $\Omega^- \to \Lambda K^-$

Data
~ 116 fb^{-1}

Background-Subtracted
Efficiency-Corrected

Entries/0.2 vs $\cos\theta(\Lambda)$
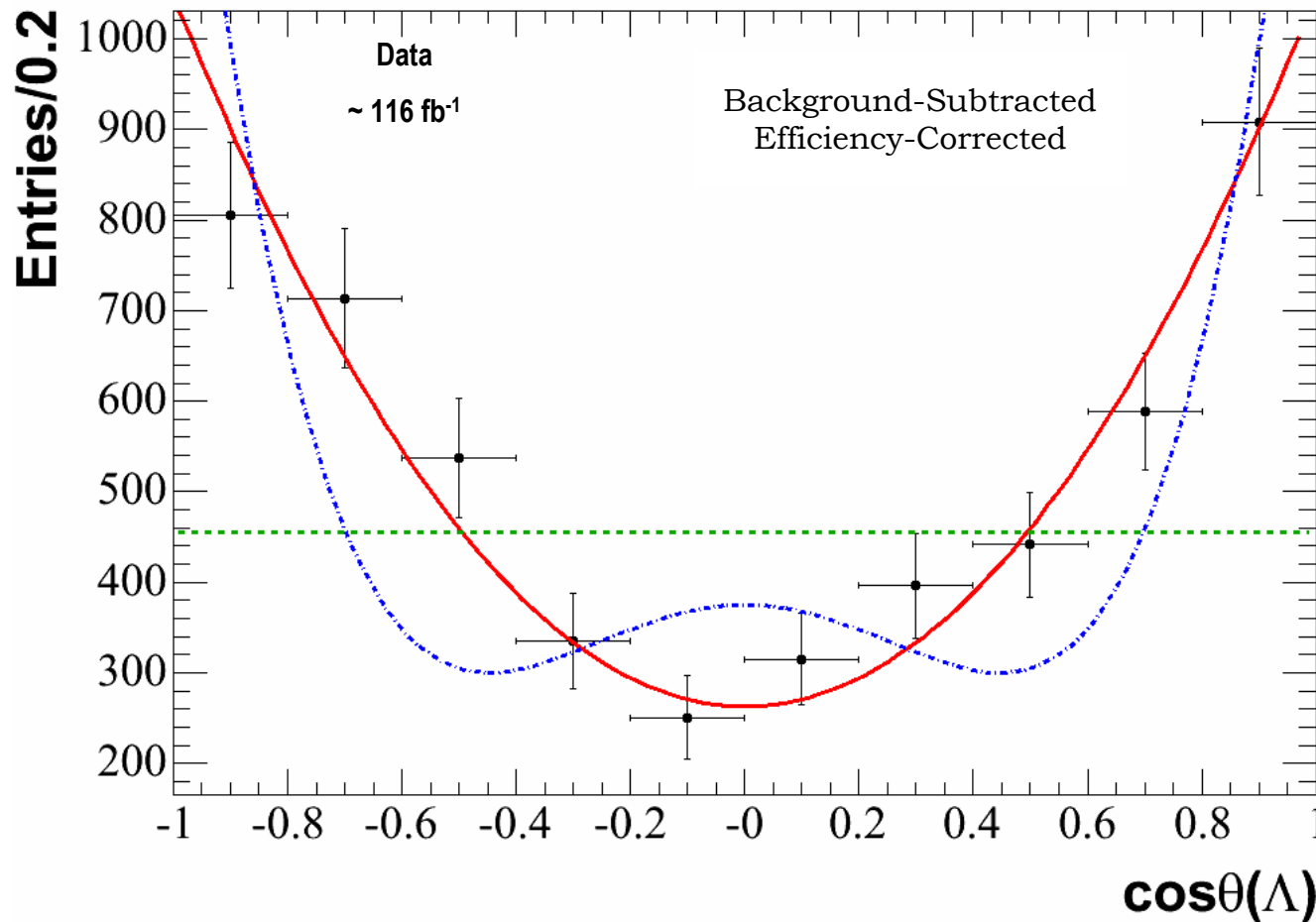
.... $J_\Omega = 1/2$ $\Rightarrow I \propto 1$ $\to$ Fit Prob = 10^{-17}

——— $J_\Omega = 3/2$ $\Rightarrow I \propto (1 + 3\cos^2\theta)$ $\to$ Fit Prob = 0.64

--- $J_\Omega = 5/2$ $\Rightarrow I \propto (1 - 2\cos^2\theta + 5\cos^4\theta)$ $\to$ Fit Prob = 10^{-7}

$J_\Omega \geq 7/2$ **also excluded**: angular distribution increases more steeply near $\cos\theta \sim \pm1$
and has $(2 J_\Omega - 2)$ turning points.

BABAR PRL **97**:112001, 2006

Angular Analysis: Σ_c spin

$\bar{P}$ ← — — B^- — — Σ_c^0 — —) θ_h — —

Λ_c^+

π^-

(Assumes $J(\Lambda_c) = \frac{1}{2}$)

Spin 1/2

Entries = 102

Events / (0.4)

toy MC sample

$\cos\theta$

Spin 3/2

Entries = 102

Events / (0.4)

toy MC sample

$\cos\theta$

Angular Analysis: Σ_c spin

"pure signal" toy MC samples

Spin 1/2   Spin 3/2

$\Delta \log(L)$
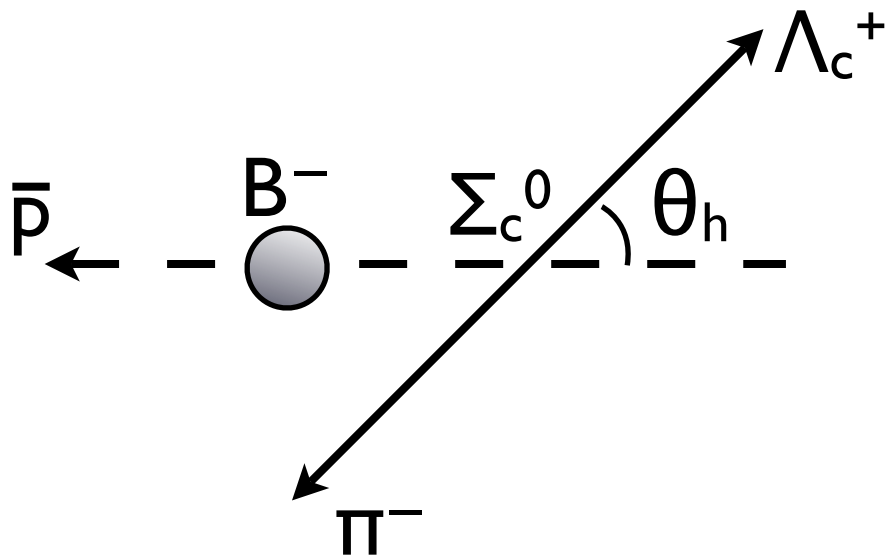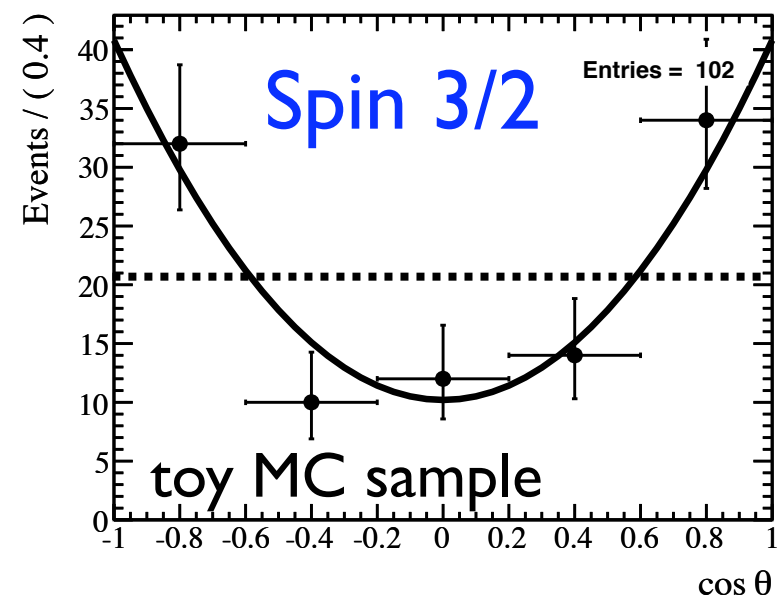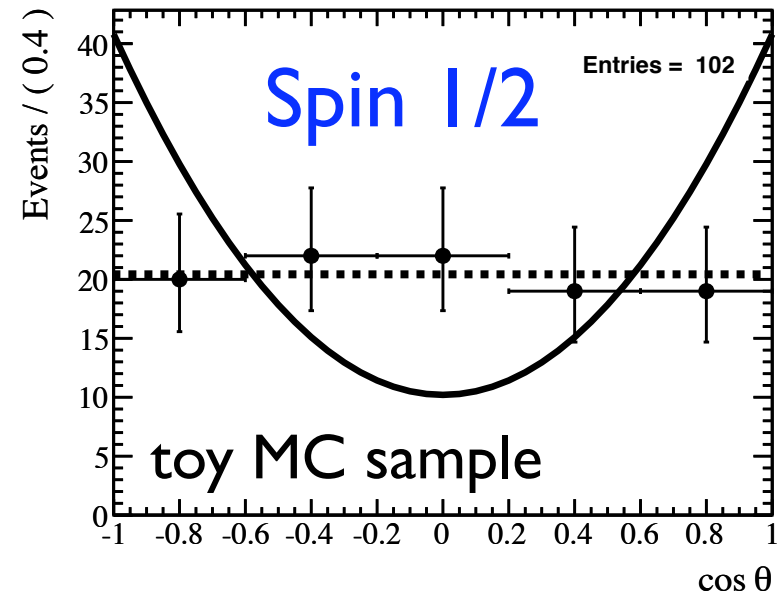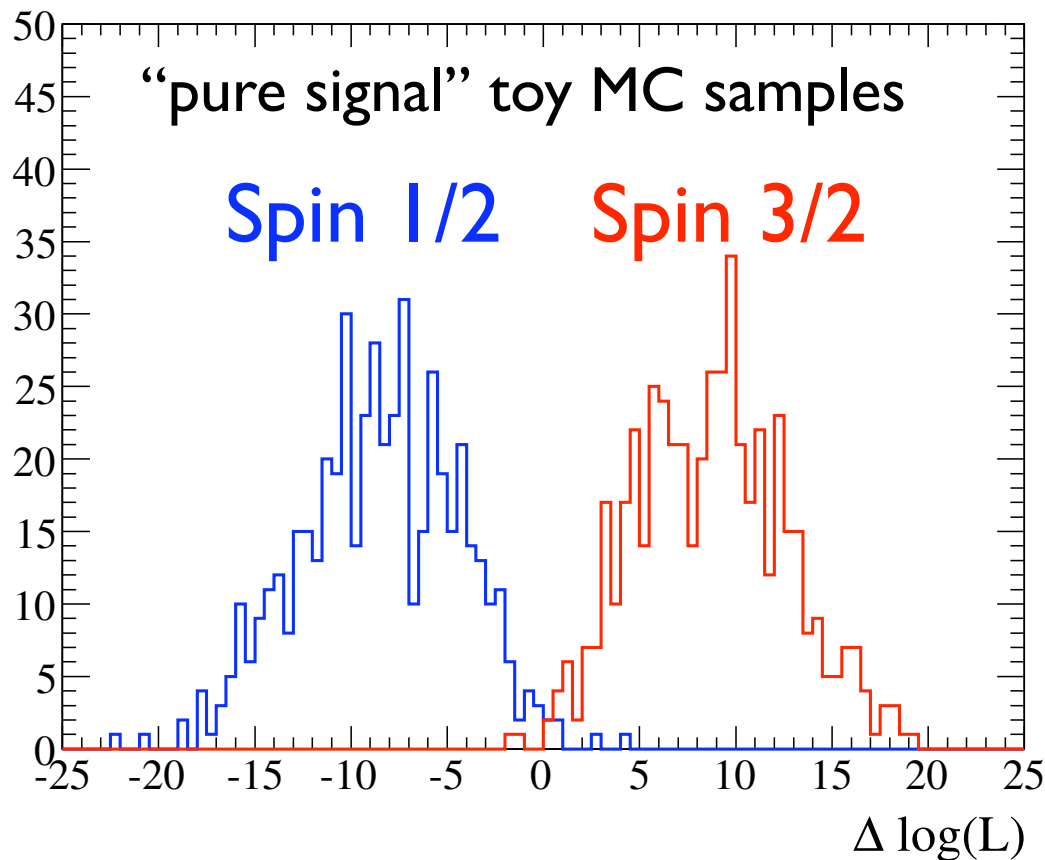
1. Generate 500 toy MC samples for each spin hypothesis
2. Determine likelihood $\mathcal{L}$ for each sample
3. Given a measurement of $\mathcal{L}$ in data, determine probability for acceptance/rejection of each hypothesis

Baryonic *B* Decays: Summary

- *B* → **B** **B̄** (M) decays provide a laboratory for:
  - insight into baryon production
  - searches for exotic baryons
  - spin measurements of (charmed) baryons
  - searches for <u>new physics</u>
  - ➡ (only if baryon production is understood)
- Look for more BABAR results this summer!

Active and Exciting Area of Research at the B-Factories

Extra Slides

Compilation of B^+ Baryonic Branching Fractions
All branching fractions are in units of 10^{-6}; limits are 90% CL

In PDG2006   New since PDG2006 (preliminary)   New since PDG2006 (published)

RPP#	Mode	PDG2006 Avg.	BABAR	Belle	CLEO	New Avg.
286	$p\bar{p}\pi^+$	$3.1^{+0.8}_{-0.7}$ §		$3.06^{+0.73}_{-0.62} \pm 0.37$ ‡	< 160	$3.06^{+0.82}_{-0.72}$
289	$p\bar{p}K^+$	5.6 ± 1.0 §	$6.7 \pm 0.5 \pm 0.4$ †	$5.30^{+0.45}_{-0.39} \pm 0.58$ ‡		6.10 ± 0.48
290	$\Theta^{++}\bar{p}$ *	< 0.091	< 0.09	< 0.091		< 0.09
291	$f_J(2221)K^+$ *	< 0.41		< 0.41		< 0.41
292	$p\overline{\Lambda}(1520)$	< 1.5	< 1.5			< 1.5
294	$p\bar{p}K^{*+}$	$10.3^{+3.6+1.3}_{-2.8-1.7}$ ‡		$10.3^{+3.6+1.3}_{-2.8-1.7}$ ‡		$10.3^{+3.8}_{-3.3}$
295	$p\overline{\Lambda}$	< 0.49		< 0.29	< 1.5	< 0.29
299	$\Lambda\overline{\Lambda}\pi^+$	< 2.8 ‡		< 2.8 ‡		< 2.8 ‡
300	$\Lambda\overline{\Lambda}K^+$	$2.9^{+0.9}_{-0.7} \pm 0.4$ ‡		$2.9^{+0.9}_{-0.7} \pm 0.4$ ‡		$2.9^{+1.0}_{-0.8}$

† Charmonium decays to $p\bar{p}$ have been statistically subtracted.

‡ The charmonium mass region has been vetoed. * Product BF - daughter BF taken to be 100%:
$\Theta(1540)^{++} \to K^+ p$ (pentaquark candidate);

Heavy Flavor Averaging Group
March 2007

Compilation of B^0 Baryonic Branching Fractions
All branching fractions are in units of 10^{-6}; limits are 90% CL

In PDG2006   New since PDG2006 (preliminary)   New since PDG2006 (published)

RPP#	Mode	PDG2006 Avg.	BABAR	Belle	CLEO	New Avg.
266	$p\overline{p}$	< 0.27	< 0.27	< 0.10	< 1.4	< 0.10
268	$p\overline{p}K^0$	$2.1^{+0.6}_{-0.4}$ §		$2.40^{+0.64}_{-0.44} \pm 0.28$ ‡		$2.40^{+0.70}_{-0.52}$
269	$\Theta^+ K^0$ †	< 0.23		< 0.23		< 0.23
270	$p\overline{p}K^{*0}$	< 7.6 ‡		< 7.6 ‡		< 7.6 ‡
271	$p\overline{\Lambda}\pi^-$	2.6 ± 0.5 §	$3.30 \pm 0.53 \pm 0.31$	$3.27^{+0.62}_{-0.51} \pm 0.39$	< 13	$3.29^{+0.47}_{-0.44}$
272	$p\overline{\Lambda}K^-$	< 0.82		< 0.82		< 0.82
273	$p\overline{\Sigma}^0\pi^-$	< 3.8		< 3.8		< 3.8
274	$\Lambda\overline{\Lambda}$	< 0.69		< 0.32	< 1.2	< 0.32

§Di-baryon mass is less than 2.85 GeV/c^2; ‡ The charmonium mass region has been vetoed.
† Product BF - daughter BF taken to be 100%; $\Theta(1540)^+ \rightarrow pK^0$ (pentaquark candidate).

Table 1: Branching fractions of neutral B modes producing baryons in units of 10^{-5}, upper limits are at 90% CL. The latest version is available at: http://hfag.phys.ntu.edu.tw/b2charm/00203.html

Mode	PDG 2006	Belle	BABAR	CDF	Average
$J/\psi(1S)\bar{p}p$	< 0.083	< 0.083	< 0.190		$\mathbf{< 0.083}$
$\Lambda_c^+\bar{p}$	2.20 ± 0.80	$2.19 \pm^{0.56}_{0.49} \pm 0.32 \pm 0.57$	$2.15 \pm 0.36 \pm 0.13 \pm 0.56$		2.17 ± 0.53
$\Sigma_c^{*0}\bar{p}\pi^+$	< 12.1	< 12.1 [1]			$\mathbf{< 3.3}$
		< 3.3 [2]			
$D^{*0}(2007)p\bar{p}$		$12.0 \pm^{3.3}_{2.9} \pm 2.1$	$6.70 \pm 2.10 \pm 0.82 \pm 0.36$ [3c]		11.1 ± 1.3
			$11.00 \pm 1.00 \pm 0.90$ [4c]		
$D^0 p\bar{p}$		$11.8 \pm 1.5 \pm 1.6$	$12.40 \pm 1.40 \pm 1.16 \pm 0.30$ [3b]		11.39 ± 0.91
			$11.30 \pm 0.60 \pm 0.80$ [4b]		
$\Sigma_c^{*++}\bar{p}\pi^-$	16.0 ± 7.0	$16.3 \pm^{5.7}_{5.1} \pm 2.8 \pm 4.2$ [1]			$\mathbf{12.9 \pm^{3.3}_{3.4}}$
		$12.0 \pm 1.0 \pm 2.0 \pm 3.0$ [2]			
$\Sigma_c^0\bar{p}\pi^+$	10.0 ± 8.0	$14.0 \pm 2.0 \pm 2.0 \pm 4.0$ [2]			$\mathbf{14.0 \pm 4.9}$
		< 15.9 [1]			
$\Sigma_c^{++}\bar{p}\pi^-$	28.0 ± 9.0	$23.8 \pm^{6.3}_{5.5} \pm 4.1 \pm 6.2$ [1]			$\mathbf{21.8 \pm^{5.1}_{5.2}}$
		$21.0 \pm 2.0 \pm 3.0 \pm 5.0$ [2c]			
$D^+ p\bar{p}\pi^-$			$38.00 \pm 3.50 \pm 4.50 \pm 0.95$ [3a]		33.8 ± 3.2
			$33.8 \pm 1.4 \pm 2.9$ [4a]		
$D^{*+}(2010)p\bar{p}\pi^-$	65 ± 16		$56.1 \pm 5.9 \pm 6.4 \pm 3.6$ [3d]		48.1 ± 4.9
			$48.1 \pm 2.2 \pm 4.4$ [4d]		
$\Lambda_c^+\Lambda_c^-\bar{K}^0$		$79 \pm^{29}_{23} \pm 12 \pm 41$			$\mathbf{79 \pm^{52}_{49}}$
$\Lambda_c^+\bar{p}\pi^+\pi^-$	130 ± 40	$110 \pm^{12}_{12} \pm 19 \pm 29$			110 ± 37

[1] STUDY OF EXCLUSIVE B DECAYS TO CHARMED BARYONS AT BELLE. (31.7M $B\bar{B}$ pairs)

[2] Study of the charmed baryonic decays $\bar{B}^0 \to \Sigma_c^{++}\bar{p}\pi^-$ and $\bar{B}^0 \to \Sigma_c^0\bar{p}\pi^+$ (386M $B\bar{B}$ pairs) ; [2c] B0bar to Sigmac(2455)++ pbar pi

[3] Measurement of the Branching Fraction for the decays $\bar{B}^0 \to D^{*+}p\bar{p}\pi^-$, $\bar{B}^0 \to D^+ p\bar{p}\pi^-$, $\bar{B}^0 \to \bar{D}^{*0}p\bar{p}$, $\bar{B}^0 \to \bar{D}^0 p\bar{p}$ (124M $B\bar{B}$ pairs) ; [3a] $\bar{B}^0 \to D^+ p\bar{p}\pi^-$; [3b] $\bar{B}^0 \to \bar{D}^0 p\bar{p}$; [3c] $\bar{B}^0 \to \bar{D}^{*0}p\bar{p}$; [3d] $\bar{B}^0 \to D^{*+}p\bar{p}\pi^-$

[4] Measurements of the Decays $B^0 \to \bar{D}^0 p\bar{p}$, $B^0 \to \bar{D}^{*0}p\bar{p}$, $B^0 \to D^- p\bar{p}\pi+-$, and $B^0 \to D^- p\bar{p}\pi^+$ (232M $B\bar{B}$ pairs) ; [4a] $\bar{B}^0 \to D^+ p\bar{p}\pi^-$; [4b] $\bar{B}^0 \to \bar{D}^0 p\bar{p}$; [4c] $\bar{B}^0 \to \bar{D}^{*0}p\bar{p}$; [4d] $\bar{B}^0 \to D^{*+}p\bar{p}\pi^-$

Mode	PDG 2006	Belle	BABAR	CDF	Average
$\Lambda_c^-\Xi_c^+[\Xi^-\pi^+\pi^+]$		$9.3 \pm^{3.7}_{2.8} \pm 1.9 \pm 2.4$			$\mathbf{9.3 \pm^{4.8}_{4.1}}$

Table 1: Branching fractions of charged B modes producing baryons in units of 10^{-5}, upper limits are at 90% CL. The latest version is available at: http://hfag.phys.ntu.edu.tw/b2charm/00103.html

Mode	PDG 2006	Belle	BABAR	CDF	Average
$J/\psi(1S)\Sigma^0\bar{p}$	< 1.10	< 1.10			$\mathbf{< 1.10}$
$J/\psi(1S)\Lambda\bar{p}$	1.18 ± 0.31	$1.16 \pm 0.28\pm^{0.18}_{0.23}$	$1.16 \pm^{0.74}_{0.53} \pm^{0.42}_{0.18}$		$\mathbf{1.16 \pm 0.31}$
$D^{*+}(2010)p\bar{p}$		< 1.50			< 1.50
$D^+p\bar{p}$		< 1.50			< 1.50
$\Sigma_c^{*0}\bar{p}$	< 4.6	< 4.6			< 4.6
$\Sigma_c^0\bar{p}$	< 8.0	< 9.3			< 9.3
$\Lambda_c^+\bar{p}\pi^-$	21.0 ± 7.0	$18.7 \pm^{4.3}_{4.0} \pm2.8 \pm 4.9$	$35.3 \pm 1.8 \pm 3.1 \pm 9.2$		$24.2\pm^{5.6}_{5.7}$
$\Lambda_c^+\Lambda_c^-K^-$		$65.0 \pm^{10.0}_{9.0} \pm11.0 \pm 34.0$			$\mathbf{65 \pm 37}$

Table 2: Product branching fractions of charged B modes producing baryons in units of 10^{-5}, upper limits are at 90% CL. The latest version is available at: http://hfag.phys.ntu.edu.tw/b2charm/00103.html

Mode	PDG 2006	Belle	BABAR	CDF	Average
$K^-\eta_c(1S)[\Lambda\bar{\Lambda}]$		$0.095 \pm^{0.025}_{0.022} \pm^{0.008}_{0.011}$			$\mathbf{0.10 \pm 0.03}$
$K^-\eta_c(1S)[p\bar{p}]$	0.12 ± 0.04	$0.14 \pm 0.01\pm^{0.02}_{0.02}$	$0.18 \pm^{0.03}_{0.02} \pm0.02$		$\mathbf{0.15 \pm 0.02}$
$K^-J/\psi(1S)[\Lambda\bar{\Lambda}]$		$0.20 \pm^{0.03}_{0.03} \pm0.03$			$\mathbf{0.20 \pm 0.05}$
$K^-J/\psi(1S)[p\bar{p}]$	0.22 ± 0.01	$0.22 \pm 0.01 \pm 0.01$	$0.22 \pm 0.02 \pm 0.01$		$\mathbf{0.22 \pm 0.01}$
$\Lambda_c^-\Xi_c^0[\Xi^-\pi^+]$		$4.80 \pm^{1.00}_{0.90} \pm1.10 \pm 1.20$			$\mathbf{4.8 \pm 1.9}$

Table 3: Ratios of branching fractions of charged B modes producing baryons in units of 10^0, upper limits are at 90% CL. The latest version is available at: http://hfag.phys.ntu.edu.tw/b2charm/00103.html

Mode	PDG 2006	Belle	BABAR	CDF	Average
$\frac{\mathcal{B}(B^-\to\Lambda_c^+\bar{p}\pi^-)}{\mathcal{B}(\bar{B}^0\to\Lambda_c^+\bar{p})}$			$16.4 \pm 2.9 \pm 1.3$		16.4 ± 3.2